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Proceedings of the Second Allerton Conference
December, 1971

ENVIRONMENTAL QUALITY AND AGRICULTURE

WHAT ARE THE OPTIONS?

COUNCIL ON ENVIRONMENTAL QUALITY
COLLEGE OF AGRICULTURE
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Summary of Conference

The Council on Environmental Quality of the College of Agriculture is pleased to present the Proceedings of the Second Allerton Conference, "Agriculture and Environmental Quality—What Are the Options." The conference and its proceedings are evidence of continuing progress, both within the College and the Council, in developing strong interdisciplinary research programs aimed at solving some of the most vexing problems related to agriculture.

The first Allerton Conference, held in December, 1970, was an effort on the part of the Council on Environmental Quality to explain its organization and objectives as well as to outline and emphasize specific areas of environmental concern that needed attention. This was done through a series of task group reports that discussed problems from the standpoint of needs in research, education, and public service.

In contrast, the second conference was more specific in that the same task groups reported progress that had been made during the year, either in actual on-going research or in developing research plans and programs in specific problem areas. The second conference also differed from the first in that it provided a forum for representatives of government, industry, environmental and conservation groups, and concerned citizens to express their views and philosophies on agriculture's role in maintaining an environment that is worthy of our heritage. In this part of the program, we were fortunate indeed to have the participation of Senator Charles H. Percy of Illinois. Senator Percy expressed a philosophy that should receive serious thought by all facets of the public. He stated, "As human beings, as consumers, we all live in environmental glass houses, and we will achieve nothing if we continue to throw stones at each other. If we are sincerely interested in preserving and protecting our Earth, it is futile to assess blame for the conditions we face today."

Environmental quality, as we think of it today, was placed in the socio-political context of population's growth and needs for food and fiber by W. W. Erwin, a farmer and agricultural adviser to William Ruckelshaus, Director of the Federal Environmental Protection Agency. He emphasized that environmental improvement is not just a fad but a reality which must be faced. Mr. Erwin emphasized the insecurity felt by farmers. The demands of our increasing population for high-quality food and the cry against using pesticides and fertilizers often put a farmer in what appears to be an uncompromising middle ground. Under these conflicting demands, the farmer may ask, "Can I compete?" Erwin suggested that the answer is debatable.

The balance of agricultural research throughout the country, as it relates to current environmental problems, was discussed by R. J. Hildreth, Managing Director of the Farm Foundation. He pointed out that although 21 percent of the scientific man-years devoted to agricultural research in 1970 was aimed at increasing efficiency of production, while only 1.7 percent was directly related to pollution, we should not assume that this means a gross imbalance. Quite often research on increasing production may have beneficial environmental quality effects. He developed the thought that the problem of residuals (pollutants) in the environment relates to failure of legal and economic institutions to relate to the rapid rise in economic value of environmental services from our "common property" of air, water, and space. In this respect the need to look at alternative institutional structures that will lead the polluters and the polluted to count pollution as their own cost was emphasized.

Discussions by task group leaders and representatives presented research results that are encouraging and, in some cases, dramatic. Dr. R. L. Metcalf, speaking on behalf of the task group on pesticides and pest control systems, presented results of his research to modify the DDT molecule so that it would continue to be an effective insecticide but would not accumulate and magnify in food chains. He described several DDT analogs that have been tested in a unique and novel model ecosystem which show great promise and, in truth, may represent a scientific "break-through" perhaps as great as the original discovery of DDT. Dr. Metcalf emphasized that a major objective of the task group was how to best use "better" pesticides once they are found.

Progress on several individual projects was reported by the task group on animal and human metabolic wastes. Results from studies on refeeding swine wastes that can be recovered from the oxidation ditch mixed liquor (ODML) are particularly intriguing and suggest again that the idea of reuse of waste rather than mere disposal is the ultimate goal of all task groups dealing with waste problems. Solid material that passed through a 200-mesh screen was rich in some of the essential amino acids and when refed, along with additional corn and soybean materials, produced gains that were slightly better than those from feeding standard feed mixtures.

The task group also reported on the continuing research on the use of anaerobically digested sludge on agricultural lands. Heavy metals, a source of major concern, were shown to accumulate in the soil but appeared to be resistant to leaching. Fecal coliform populations, another source of concern, decreased by 99.9 percent within 30 days after sludge was either placed in storage or applied to the soil.

Another use of sludge, its use in ameliorating soil conditions on acid strip-mine spoils, was discussed by Charles J. Hendricks, Supervisor of the Shawnee National Forest. Small-scale tests gave very favorable results, both from the standpoint of revegetation, decreasing acidity, and reduction in heavy metals and other undesirable components in the subsurface leachate.

"The conversion of residues from liabilities to assets" was stated as the primary objective of research conducted by members of the wood and food processing wastes task group. Results indicate that the objective is being achieved, especially with wood residues. The utilization of hardwood bark is a reality, and in less than five years there is a shortage rather than a surplus of this material that was formerly burned or dumped. Important uses are in ornamental horticulture as a growth medium for potted plants and for mulching shrub beds and exposed cuts and fills on highway construction projects. Promising results are also being obtained in possible uses of wood residues in fabricating panel boards that are adaptable to a wide range of uses.

Food scientists have learned that the undesirable "painty" taste of field soybeans is due to an enzyme that becomes active as soon as the bean is broken. Fortunately the enzyme action can be prevented by cooking the whole bean in boiling water. A simulated milk product, along with many promising foods, has been developed. Mixing the soya-milk with cottage cheese whey, a waste from dairy processing, produces a tasty and nutritious product which shows considerable promise for commercial use.

The problem of high nitrate in water and its possible effects on human and livestock health has been given a high priority by several task groups, but mainly by those concerned with plant nutrients as water pollutants. Health aspects were discussed by Dr. K. W. Sloan, Associate Dean, College of Veterinary Medicine, and Dr. David H. Gunderson of the Federal Environmental Protection Agency. Livestock losses from "nitrate poisoning," or more properly nitrite toxicosis, have been more commonly associated with the ingestion of high-nitrate foods rather than of water. However, the role of the latter is not clearly defined. Dr. Gunderson reported on a study of the health of young children (1 to 4 years old) in Washington County, Illinois, who had been subject to drinking high-nitrate water. No great health effects were found when the "high-nitrate group" was compared with a "low-nitrate group." It should be emphasized that most cases of methemoglobinemia occur in younger age groups than those tested, generally those less than six months of age and not on solid food.

Progress on research specifically related to the occurrence of high nitrate in shallow wells of the claypan area indicate that the major source appears to be from metabolic wastes of livestock and human populations, rather than from nitrogen fertilizers. However, amounts of nitrate that have accumulated in the soil seem to be greater than can be accounted for by specific sources.

Alternate sources of water, other than shallow wells, have received considerable attention. Farm ponds as a possible source are being intensively studied. Economic aspects of various alternatives have been investigated and reported.

Environmental quality is not just a technological problem but has many social overtones. Decisions and actions of man have created the problems, and only man can devise corrective actions and regulatory mechanisms. Will individual communities accept recommended practices and regulations required to improve environmental quality? This question was posed and discussed by the task group on "social assessment." Two research projects in this extremely important area were discussed. One of these concerns the idea of community mobilization for the purpose of meeting the challenge of improving environmental quality. The other examines responses of individuals and communities to the issue of alleged water pollution from fertilizers. This work is being centered on Lake Decatur where considerable controversy exists with regard to excess nitrate in public water supplies and its possible health effects.

Discussions from the various groups—industry, government, environmental, etc.—were most helpful in providing the Council with thoughts, ideas, and background materials upon which future programs in research, teaching, and public service may be based. To each of these participants we express our gratitude for their attendance and participation. The Council has made considerable progress in two short years. But progress in research is only one side of the coin. Communications with the public are essential so that all concerned will have a better understanding of our common problems and possible solutions to them. The Council sincerely hopes that this Second Allerton Conference has accomplished a part of this essential communications ingredient.

Opening Remarks

It is my happy responsibility to open the Second Allerton Conference on Agriculture and the Quality of the Environment. I am Glenn Salisbury, Director of the Illinois Agricultural Experiment Station. And what, pray tell, is the Illinois Agricultural Experiment Station? Well, the Illinois Agricultural Experiment Station is, or at least a part of it is, scattered through the audience. The Agricultural Experiment Station is your host for the two-day conference on the theme of "Agriculture and Environmental Quality—What Are the Options?"

The Agricultural Experiment Station is, in fact, an organization of faculty members of the College of Agriculture of the University of Illinois at Urbana-Champaign. It was created first by an act of Congress in 1881 and accepted as a state responsibility by the Illinois legislature later. As early as 1871, however, the state appropriated funds for the purchase of farm lands on which to do research pertaining to agricultural problems in Illinois, and on the present campus a small part of that purchase is now a national historic landmark: the Morrow Plots, the oldest continuous research plot in the world. Its present research is done on a project basis and financed both by the state and federal government and by some grants.

We are trained in many different scientific disciplines, and our departments, of which we are members, bear titles such as Agronomy, Horticulture, Food Science, Agricultural Economics, Agricultural Engineering, Dairy Science, Plant Pathology, Home Economics, Animal Science, and Forestry. Each name tells something about what things we work with, but not much about how we go about it.

Who are the rest of you? Some of you are our colleagues from other colleges of the University; all are concerned people and interested in the environment. Others are legislators, business men and women—all concerned people whom we have invited here to sit with us and consider seriously some of the pressing problems of our times. Each of us will look at the problems of our environment as they relate to agriculture and to the well-being of people everywhere, from the prison of our own backgrounds and experience.

I, for example, am a biologist; I have dealt all my life with the problems of reproduction in farm animals and with their genetic improvement. I have witnessed the difficulties with which change is made in a species, and I am concerned that the rate of the changes in the environment we now witness is too fast for proper adaptation by the evolutionary process.

Thus, to me the problems being generated today are primarily biological. The solution to those problems must be made by changing the environment and the answers to such change lie in the fields of law, economics, sociology, and politics. Others of you will have other vantage points as you view problems with us. The crux of the issue is that we must tackle them in a concerted way with all of the power and knowledge available to us. Thus we have asked you to meet with us, to consider these issues which relate to "Environmental Quality and Agriculture—What Are the Options?"

Our task for these two days was put pretty well by the British biologist Julian Huxley about 22 years ago when he pointed out that man of all biology on earth was unique in his capacity for rational and conceptual thinking. He said in that essay, "In the perspective of biology, our business in the world is seen to be the imposition of the best and most enduring of our human standards upon ourselves and our planet. The enjoyment of beauty and interest, the achievement of goodness and efficiency, the enhancement of life and its variety—these are the harvest which our human uniqueness should be called upon to yield."

That, then, is the purpose of this conference!

Remarks by G. W. Salisbury, Director, Illinois Agricultural Experiment Station, College of Agriculture, University of Illinois at Urbana-Champaign.

Welcome

The College of Agriculture is pleased to welcome the participants in the second Allerton Conference on environmental quality. This is a working conference, designed to provide a benchmark for evaluating progress since the first conference held here a year ago. Among others, the participants in this conference come from at least four colleges of the Urbana-Champaign campus and have been brought together by their common concern for environmental problems which, in this instance, are focused on agriculture and the use of renewable resources in the production of food.

Agricultural scientists are legitimately concerned about the quality of the environment and the pollution of resources used in the production of plant and animal products. But in this state there is a broader concern—one that extends to the quality of the environment as it touches the lives of people in urban as well as rural America. The deterioration of the environment is brought on largely by the impact of increased population and the demand for goods to sustain the standard of living that has typified America. This relationship between agriculture and the demand for goods illustrates how closely related agriculture is to the central issues of environment on a national and global scale. Even though environmental problems are global in nature, if we are discerning scientists, we must be able to pinpoint specific aspects of environmental deterioration that will respond to research, to change through educational efforts, and to the application of technology. We are dealing, too, with value judgments that go to the heart of a society's economic and cultural mores.

In thinking about remarks that might set the tone of our conference, I would like to quote from two distinguished Americans, as their words, though given in a different context, seemed to sum up in a concise way two general objectives that we might hold for our conference here.

The first one deals with the impact of science and technology on the environment and the posture we as educators and scientists should take in viewing the problems of the environment. I quote from the outstanding speech given by National Academy of Science President Dr. Philip Handler in a 1970 W. O. Atwater Memorial Lecture, which he entitled, "Can Man Shape His Future?"

"The current overly emotional worldwide awakening to the undesirable side effects of some facets of our technological civilization has led to diminution in public support of the scientific endeavor. Whether this derives from simple know-nothing anti-intellectualism, informed repugnance, or simple ignorance, the effect is the same—demands for a moratorium in the pace of the scientific endeavor, reduction in support for the education of tomorrow's scientists.

"I could not disagree more violently. For all of our difficulties, the fact remains that the technology science makes possible is the principal tool this civilization has fashioned to alleviate the condition of man. If life is to be better tomorrow than it was yesterday, we shall require more and better science-based technology rather than less. If we retreat from scientific research today, if we fail to educate a large, diversified corps of scientists, some capable of working at the disciplinary frontiers, others trained and motivated to function in multi-disciplinary teams gathered to address one of the multitudinous societal problems, we shall also fail to construct a platform for the technology of tomorrow, and our great-grandchildren will not thank us."

And now I would like to quote from some remarks made recently by the distinguished author and educator, Peter F. Drucker, which he entitled, "Politics and Economics of the Environment." He addresses the broad issues that are implicit in a commitment to resolve the pressing problems of the environment. After identifying himself as a "very old environmentalist," he singled out at least two major philosophical shortcomings to the approaches made by many people in solving environmental problems.

"The first thing to say is that most of the present advocates of the environment suffer from three major misunderstandings which inhibit results. The first misunderstanding, and the one that bothers me the most is that we think that one can live in a riskless universe, that one can somehow deprive human action of risk. To believe that one can be safe is a sheer delusion. The real challenge in the environmental situation is to think through what risks to afford and what risks are not permissible and where to draw the line, and what price to pay for what degree of insurance. That is taboo and anathema to the mood of today. Yet the whole history of the human race proves that one always pays a price and the decision is how much to pay. One takes risks, and the crucial decision is what risks are intelligent and prudent risks. The moment you want to be riskless, you are endangered and you are vulnerable to the wrong catastrophes.

"We are, for instance, not thinking through the risk we are taking in not building enough electric power. Yet the entire environmental technology is a power technology. Everything we need to do to clean up the environment raises the energy needs by several orders of magnitude. To be sure, building electric power stations has its problems. But by not building them we are just laying ourselves open to catastrophic dangers not very far out.

"The second misunderstanding is that somehow profits can pay the costs of managing the environment. Yet we have known for a long time that there is no such thing as profit anyhow; that's an accounting delusion. There are only the costs of the past and the costs of the future.

Remarks by Dean Orville G. Bentley, College of Agriculture, University of Illinois at Urbana-Champaign.

"Finally there is the misunderstanding that it is 'greed' that explains the environmental crisis. No, it is largely the desire not to see two out of three children die before they reach age five; to have enough to eat for the poor and to have access to job and opportunity. The environment is a problem of success.

"These are the hardest problems. They do not yield to attack by morality; they have nothing to do with it."

Drucker then summed up what appeared to be the challenge to government, scientists, and educators by saying that perhaps the greatest single problem we face is that we are unwilling, as a nation, to set priorities in the attack on pollution of the environment. All the excitement in a discussion of the environment will lead to few tangible results unless we develop a policy aimed at finding solutions to specific problems related to the need to provide food for a rapidly expanding world population. Drucker relates the problems of food production to air and water pollution and suggests the need for a new technology. He states: ". . .we are caught in a dilemma between having millions of children die as a result of a sharp drop in crop yields if we stop using herbicides and pesticides, and doing inevitable ecological and biological damage because the pesticides and herbicides are too potent. In the long run this may be the most tragic problem we face. But so far, few people are even working on the problem."

The last statement appears to set forth a specific challenge for those of us who are brought together in a common concern over the maintenance of the quality of the environment and the conservation of renewable resources for future generations, on the one hand, and the growing need to preserve an efficient and productive agriculture for posterity, on the other hand.

Finally, I want to close by commending Professors Boggess and Miller for the leadership they have given the Council on Environmental Quality, which is now slightly more than two years old. It has had a profound effect upon the College of Agriculture in bringing together people from many areas who have a mutual interest in problems related to the environment. The Agricultural Experiment Station, as an integral part of the research efforts of the College of Agriculture, is the logical "home" for the Council on Environmental Quality. The Council needs the strong back-up support it is receiving from Director G. W. Salisbury.

As the program over the next 2½ days unfolds, I think you will find that here is a group of scientists and educators which has made a commitment to work on problems of the environment. I hope you will continue the process of setting realistic priorities and identifying areas for research and extension as was suggested in the remarks by Dr. Handler and Dr. Drucker.

Food, Population, and Environmental Quality

I was invited to speak on a rather complicated subject—the political-social environment in which questions of the environment will be studied. I want to say at the outset that I am a consultant of Mr. Ruckelshaus, but I do not speak for the Environmental Protection Agency, or for Mr. Ruckelshaus.

What about the society we live in? The first thing you notice today is that there are simply more people. I think we overlook the importance of congestion in our culture. When you push people together, you get a response of resistance and the response is different from that of a diversified population such as we have had in our history. Today people have more leisure, more time to think, more time to relax. They are more interested in what they are going to do with their spare time. They are less pressed by economic necessities.

We live in a culture of great wealth. We say this all of the time, but I don't think our generation—fellows of my age—really recognizes how the next generation views this wealth. We had hard times on the farm when I was a kid, and they have made their imprint on me. My son, who is a junior at MIT in Boston, is very frugal, but not for the same reasons I am. He says it is inconceivable that in my lifetime I will ever have a physical need that will not be met: a need for medical care or for food, clothing, housing. This is the young voter coming on. He was raised in this kind of wealth, and his responses are different from mine.

Today we have an extremely mobile population. People who are mobile are aware of what is going on around them. We no longer have the kind of isolation that we had before, in which interest groups compounded themselves with their own thinking. Things are always changing. At the same time, man's ability to change his environment is increasing, and man's ability to measure this change is increasing and hence causing some degree of anxiety. We are learning a lot of things we didn't know before, and some of the things we learn are frightening. Many of the frightening aspects of our society have been there for a long time too.

We live in a culture which for economic and other reasons feeds on anxiety. We watch television, probably the great educator in America today, and what do advertisers do? They make you insecure. If you use the wrong cigarettes, you might not be socially acceptable. Or if you use the wrong soap you might have "body odor." You

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Remarks by W. W. Erwin, agricultural adviser to William Ruckelshaus, federal Environmental Protection Agency.

listen to a politician, and he tries to make you insecure so that he then can tell you how he is going to take care of all the things you can't take care of yourself.

Now consider the political environment in which issues affecting agriculture and the environment are studied. Farmers are the minority group today. We farmers get awful tired of hearing about that, but it's true. The farm bloc now consists of about 5 percent of the total U.S. population.

We are 5 percent of the population, but I live in a really marginal farming area compared with Illinois, and I have to deal with many young fellows in real financial stress. Recently I talked with some representatives in Washington about how agriculture compares with the rest of the economy in return per hour of labor and rate earned per dollar invested. They said it runs along at about 70 percent, and last year it got up to 78 percent. In other words the rural community is getting about two-thirds to three-fourths as much return for its dollar as the rest of the society. And the rural community continues to become a smaller and smaller minority. What happens when minorities become small? They become militant. What happens when this minority of farmers becomes militant? You begin to hear talk from the young farmers about such things as the "agricultural establishment," and you hear resentful talk. They say farm organizations no longer represent them, that the farm organizations are tied up with the co-ops and the co-ops are selling products. They say the organizations really represent agribusiness, not the small farmer. They say that the state universities get research grants from all the big companies and don't care about the struggling farmer. They look at agribusiness and say it is making money by selling products but really doesn't care about farmers. They look at the USDA, and they say that's the bureaucracy; government people are drawing big wages, but they don't work the hours farmers do.

I don't say that their accusations are fair, but I do say that we are going to hear more of them and we should be prepared to deal with them. We must also consider the consumer ecologist group. They read about pesticides and about safety of food and they want safe food. Many of these people are absolutely convinced that we are poisoning our foods. Recently on the Today Show, I heard Hugh Downs say point-blank that "the food didn't taste good because of all the poisons on the food." They wonder why we don't simply cut down on use of all pesticides and take these poisons out of our food.

I hear people asking whether fertilizer is hurting the environment. Consumer ecologists say, "Cut down on that too." Somebody says, "Oh, people will starve." And they say, "Nonsense. We're retiring thousands and thousands of acres, and we have a tremendous food plant here sitting idle. Let's just put that plant in gear, cut down on the practices hurting our food and hurting our ecology, and quit fooling ourselves." Those of us in agriculture know the answers to many of these statements. But talk to an urban housewife someday, and see if you convince her by complex background answers. You may give her a great deal of information but you really don't convince her. Keep in mind, this group is a bigger and more powerful group than farmers.

We have to also consider the views of the man interested in urban recreation. He looks at the surface of the earth and asks how is it going to serve mankind. He says more people die from being overweight than from hunger. More people are in the hospital from tension than from disease. His answer is to get all the land we can into recreation, and some people back him up. Dr. Claussen at "Resources for the Future" says that by the year 2000 only 70 million more acres will be available for intermediate recreation, and that's what you can drive through after work and on the weekends. He says about one-half of that amount will come out of forest areas and the other one-half will have to come from farmland. Claussen says that we should be redesigning this rural culture to meet the needs of a society in which people are wealthy and have more leisure. He has a good case from his point of view.

As a state senator I was on the committee that considered state parks in Indiana. We would go to the state parks and see working people there for a good time, in tents and trailers just pushed up against each other. People were lined up to use the restrooms. Our state parks were overcrowded then, and I knew that even with a knock-down drag-out in the general assembly, they weren't going to get the money because the mental institutions, the universities, the prisons, and education were going to demand the money. The need for more parks wasn't going to be met. The city man looks out and says, "That farmer is getting 70 to 80 bucks an acre for doing nothing with that land, and he's getting it out of my tax money." This is a force we're going to have to reckon with, and from that man's point of view, he is speaking from strength. He has the facts; it is his tax money. There are idle acres during a time when his opportunity for outdoor recreation for his family on his limited budget is limited.

Then there is the general shift to more emphasis on noneconomic values—at least not immediate economic values. We've had a lot of talk about environmental impact statements, and I sometimes feel the EPA gets a little discouraged with environmental impact statements because there is always need for another one. Not long ago a congressman introduced a bill to have an environmental impact statement on every bill that was introduced in Congress. I'm afraid that the Environmental Protection Agency would do nothing else if that bill passed. But the bill represents an increased emphasis on noneconomic values.

Some of our prominent, long-term national politicians were very "pro-farmer" and rather "anti-black" until there were more black people than farmers. Then you could make a case that some of them were a little more "pro-black" and a little more "anti-farmer."

I had a fine discussion with a black cab driver—until we got on the subject of agriculture. Then, in my opinion, the man was irrational. He was mad to the core because farmers got paid for doing nothing and "that was the fact." I tried to explain that they don't get rich doing nothing. I gave him all the good arguments you know, but one could not communicate with this man.

But when you really reflect on U.S. farm policy—either policy by intent or policy by default—consider that he was one of the black men who were run off the farm in the South and had to go to the urban concentration and find a new life because our policy made it more economical to retire the land than to take care of the human needs of the people who were displaced. Our society is increasingly going to demand that we face sociological impact consideration. We have made some major errors in the past because we didn't consider these impacts.

What's the challenge to agricultural leadership? I think the first challenge when you talk about agriculture and the environment is to simply face reality. We have had some pretty prominent people going over the United States saying, "Don't worry about the environment. It's just a fad." They have been saying this to farm groups. Farmers sometimes are inclined to believe this. But this business of the environment is not a fad. Management of collectable refuse costs 4.5 billion dollars a year and volume is increasing 33 percent every 10 years. Two hundred million tons of aerial contaminants cost 16 billion dollars a year. Pollutants to lakes and rivers by industry are increasing at a rate of 4.5 percent compounded annually, and noise in urban areas has increased 3,000 percent in volume since 1939.

Now think about the voter. Most voters are in urban areas, and noise alone is enough to make sure that environment is not a passing fad. The challenge to those in agriculture is to have faith and build self-confidence in people, particularly in farmers. Rumors of what farmers are going to have to do cause a great deal of anxiety. There have been a number of cases—to the best of my knowledge all premature—in which farmers have been told they are going to have to do certain things. The farmer says, "All right, but if I do, will you then assure me that I will meet the standards and that this construction will be satisfactory?" The answer has been, "No, we can't give you that kind of assurance. You just do them, and we may change our mind." Now, as far as the Environmental Protection Agency and Mr. Ruckelshaus are concerned, no standards will be demanded without the technology to achieve them. It simply is not fair for a government to ask a citizen to do something if the government can't tell the citizen how to do it. These cases have been magnified and the anxiety is tremendous. Preliminary reports on new processes cause too much economical alarm.

I suppose most of you have heard about the exciting work General Electric is doing on recycling animal waste. They use bacteria in a complicated process and break down lignin. Cattle manure comes out as a very high quality supplement for cattle. In the big western feedlots, they are talking about using such systems, and a pilot plant is going in right now. The big western lots that Illinois cattle feeders compete with have the money to do this. The Illinois feeder says, "I can't play in this ball game. It's simply too rough. The giants are going to take over, and even worse, they are going to make their own supplement out of manure. I can't sell my soybeans or hay or corn, and they're going to ruin the markets for things I can do." I know of only one Illinois operator considering use of such a system. Just 18 months ago I visited his lot and looked at the huge calf barn where they were taking day-old Holstein calves and making them into choice veal. I saw the operation again about two months ago, and the calf barn was closed up. Anxiety is a real thing because the farmer asks himself, "Can I compete?" And it's debatable whether he can.

The farmer is insecure in changing times, but insecurity is not new. I remember well as a six-year old during the height of depression when our family got down to bread and milk. I liked bread and I liked milk, but I remember the tremendous anxiety on the part of my parents. I sensed that this was real trauma to them. So anxiety is nothing new to farmers. The whole essence of our country is to put our faith in people and their ability to deal with anxious times. You know this is how our democracy began. Then Jefferson came along and said, "You can put your faith in a common man, but you have to build self-confidence in the individual citizen." How do you do that? You do that by encouraging him to own property. The government responded, and we had the cheap-land policy. Eventually the Homestead Act said, "Go out and live on the land and you can own it."

Later it became evident that this country had to provide educational opportunities because when you are educating you are also giving confidence that man can compete and hold his own in difficult times. There developed a system of public education. We had the Morrill Act and the idea that an educated property owner with self-confidence could stand up and face changing and anxious times.

Well, the challenge of the environment is a new dimension in agriculture. It is not to be feared, but it is certainly not to be ignored. The challenge is to build the self-confidence of the individual participating farmer and of the citizens. Help them to look at this problem with the knowledge and information that you can get to them, so they will have the confidence to know that they can compete. When this is done, the environment is protected and the country is built.

Agricultural Research--The Total Picture

As a major employer of land, water, space, and atmosphere, agriculture affects environment throughout the country and contributes to the mounting ecological problems as much as any other sector of economic activity. Food production and agricultural land use are major causes of the pollution of streams and water supplies. Rainfall, for example, enters uncontaminated into resources controlled by the agricultural sector but emerges laden with silt, chemicals, herbicides, insecticides, and animal wastes.

It is not, however, the inherent nature of the agricultural production process which brings about deterioration of the environment. Rather, modernization of farming has led to increased reliance on inputs from industrial sources with resulting changes in land use patterns. At an earlier stage of development, the meager capital inputs of agriculture had their origin within agriculture and were largely of organic nature. Fertility was supplied by legumes and manures produced on the farms. Pest control was similarly organic and originated from within agriculture through rotations and resistant varieties. Energy and power were farm-produced organic forms. The main linkage between agriculture and the rest of the society was predominantly a one-way flow of "uncontaminated" food.

Nonfarm capital inputs and knowledge produced by research paved the way for the changes that came. The nation's crop output can now be produced on less acreage with more intensive use of commercial fertilizers. The trend toward large-scale, industrialized production of livestock concentrates very large amounts of animal wastes at a particular location: a single feedlot can now produce more waste than a city of a million. The food industry similarly poses threats to the ecosystem through a growing volume of organic material feeding into streams and into the air at plant sites as new technology and a rising per capita income increase food processing outside the home.

At the same time that agricultural production comes to depend more on inputs from the industrial system, a wide range of fish, fowl, and other wildlife and plant species appear to be threatened. In earlier days we were often concerned only about productive uses of land and other aspects of our environment. We have come to realize that our environment has consumptive as well as productive value.

The above brief analysis[1] would suggest that the research priorities in agriculture may be out of balance. Too much emphasis may be placed on the technology of increasing food production and too little on protecting the environment. The distribution of scientific man-years among research problem areas by the state agricultural experiment stations would seem to support such a contention (Table 1). For example, we find the experiment stations allocating 1,275 scientific man-years to field crop production efficiency research (21 percent of all their research) and 1,109 SMY's to livestock and poultry efficiency research (18 percent). Compare these allocations with 334 SMY's to soil and water conservation research (5.5 percent), 211 SMY's to research on natural beauty (3.5 percent), and 106 SMY's to wildlife and fish research (1.8 percent). Only 105 SMY's (1.7 percent) are devoted directly to pollution research.

However, more detailed analysis of the individual research projects under the various categories listed raises

Table 1. Estimated Man-Years for Research in 1970 by Problem Area, National Total, State Agricultural Experiment Stations

Problem area	Scientist man-years
Administration	281.8
Research to evaluate and improve farm income	90.5
Fruit and vegetable production efficiency research	925.1
Field crops production efficiency research	1,274.8
Livestock and poultry production efficiency	1,108.7
General purpose production efficiency research	193.7
Soil and water conservation research	333.8
Remote sensing research	13.0
Fruits and vegetables marketing and distribution efficiency research	166.4
Field crops marketing and distribution efficiency research	99.9
Livestock and poultry marketing and distribution efficiency research	192.4
Marketing firm and system efficiency research	68.1
Improve agricultural statistics	4.5
Food aid programs research	2.0
Foreign market development research	12.2
Foreign agricultural development research	14.7
Food and nutrition research	118.1
Human health and safety research	141.3
Improve levels of living research	31.1
Community improvement research	144.0
Housing research	5.8
Pollution research	104.9
Watershed development research	41.2
Fire prevention research	1.0
Research on natural beauty	210.6
Outdoor recreation research	28.5
Wildlife and fish research	105.9
Forest insects and diseases research	50.2
Timber production research	145.8
Forest products marketing research	15.1
Forest products utilization research	39.9
Unclassified	60.9
Science in service of man—grand total	6,026.0

Source: Inventory of Agricultural Research, FY 1969 and 1970, U.S. Department of Agriculture, October 1970, pp. 51-52.

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[1] The analysis draws heavily on: E. C. Heady, "Alternatives in Environmental Control Through Agriculture, Comparative Trade-Offs in Developed Countries," mimeo, 1971.

Remarks by R. J. Hildreth, Managing Director, Farm Foundation.

questions about sweeping statements that our priorities are out of balance. Projects classified as field crop production efficiency research, for example, may include research on ways of improving production efficiency that actually benefit the environment or at least do not lower the quality of environment. Finding biological methods of pest control or developing new varieties of crops that reduce soil erosion would be examples. Considering the wide range of research projects, I believe it would be naive to state from the data presented in Table 1 that research priorities are necessarily out of balance. The classification of the data is such that definite conclusions cannot be drawn from them.

Further, I question the necessity of a trade-off between food production efficiency and environmental quality. The analysis in the first paragraphs of this paper may well be accurate—food production efficiency research may have increased utilization of industrial inputs, and this, along with rising food output, has led to sizable additions of harmful residuals to the environment. I do not believe, however, that increased food production efficiency need necessarily be detrimental to the environment. Increased food production may be competitive with quality of environment—that is, may increase harmful residuals, as exemplified in the case of using "hard" pesticides. But increased food production can be complementary with quality of environment, as when insects are controlled by biological methods instead of "hard" pesticides. Finally, increased food production can be supplementary and have no effect at all on residuals.

It seems to me that both the ecological fundamentalists and the food production fundamentalists are in error in their tacit assumption that there is inevitably a sharp trade-off between more food or higher quality of environment. The world does not necessarily have to choose between starving to death or dying from accumulation of residuals as population density increases. Assuredly, there is a problem of residuals from food production and processing, and if present trends continue, the problem will become larger. But what is needed is increased use of techniques and methods of food production and processing that will not add to environmental problems.

This, then, begins to suggest further directions for research in food production and processing. It is intuitively obvious that research is needed to discover methods and techniques of food production and processing that will not add to residuals or that will reduce them. Efforts are underway in the state agricultural experiment stations on these problems and could well be increased. More research is needed in the biological, physical, and social sciences to explore and exploit these opportunities.

But even today, existing techniques and methods of food processing and production which reduce residuals are not used. Why not? When research discovers new techniques and processes that would reduce pollution, will they be adopted? I do not think that any farmer or processing firm consciously is attempting to lower the quality of the environment. Yet many harmful residuals go into the environment. Why is this?

Let me suggest a line of thought which may answer these questions. Vernon Ruttan, in his presidential address to the American Agricultural Economics Association, holds that throughout history man has continuously been challenged by the twin problems of how to provide adequate subsistence for himself and how to manage the production and disposal of residuals. Ruttan says, "The current environmental crisis represents, in my view, one of those recurring times in history when technical and institutional change in the treatment of residuals has lagged relative to progress in the provisions of subsistence, conceived in the broad sense of the material component of consumption."[2] He does not blame science and technology but instead suggests that they have expanded "spaceship earth" along the dimensions that are most significant for human existence. He contends that the fundamental significance of the technical change is the substitution of knowledge for resources so that existing resources can be used more effectively; by ignoring this impact of expanded knowledge, the rhetoric about the finite earth is clearly misleading.

With this line of thought, the problem of residuals appears to lie largely in the failure of legal and economic institutions to adjust to the rapid rise in economic value of environmental services from our "common property" of air, water, and space. The institutional system governing the use of these common property resources has failed to evolve so as to account for the increased capacity required to both assimilate the residuals from production and consumption and at the same time accommodate the increased desire for environmental amenities and esthetics that is associated with rising per capita incomes.

Because they are common property, the environmental services of air, water, and space are priced at a very low level—zero in many cases. Thus, there is little incentive to adopt production and processing techniques that would lower residuals. As Ruttan points out, the capacity of environment to absorb the residuals from crop and livestock production and processing has been treated as a free good; thus, scientific and technical innovation has been overly biased toward development of land substitutes, plant nutrients, and plant protection chemicals and toward crop varieties and management systems that undervalue the social cost of disposal of residuals.

If we follow this reasoning, the solution appears clear. We need to change the social and economic institutions to bring the private cost to firms and units of government more in line with the social costs of using common property for residual disposal. This kind of reformation will not only induce firms and governmental units to use production and processing techniques that yield lower amounts of residuals but will also create more demand for technology directed toward plant varieties and soil management systems that are consistent with the social value of environmental services.

Let me attempt to illustrate this line of thought with a case study reported in *Environmental Economics.*[3] Polk County, Florida, east of Tampa, produces about one quarter of Florida's citrus crop and supports a substantial beef cattle industry. The area also contains one of the world's largest and richest phosphate rock deposits. The early use of the phosphate rock was a simple mining operation, but in the late 1940's and early 1950's a phosphate fertilizer manufacturing industry developed rapidly. The "wet process" of manufacturing triple super phosphate there liberated large amounts of gaseous and particulate fluorides. The increase in the air-borne fluorides under existing atmospheric conditions created problems for citrus growers and cattle producers: citrus growers found that the value of the groves had decreased by more than $150 an acre, and the value of pasture land had dropped about $20 an acre.

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[2] Ruttan, Vernon, "Technology and the Environment," Presidential address to the annual meeting of the American Agricultural Economics Association, 1971, staff paper P71-17, Department of Agricultural and Applied Economics, University of Minnesota.

[3] Crocker, T. A., and A. J. Rogers, *Environmental Economics,* Dryden Press, Hinsdale, Illinois, 1971.

The fertilizer manufacturing plants, however, could well afford to view the air mass as common property. Using the air mass to get rid of fluoride residuals is a very low-cost method, and if the manufacturing firms act in an economically rational way, they would not use more expensive production processes to reduce the fluoride residuals. However, this economic rationality has led to damage to the citrus and cattle producers.

I shall leave it to you to read the engaging account of the struggle and the outcome in the Polk County case. I merely wish to use the case as a backdrop to sketch out a few of the institutional alternatives for dealing with the situation. A number of alternatives come to mind.

The first might be the use of rules and regulations by some appropriate governing body. Outright banning of all pollutant materials might be one answer. A little thought, however, leads to the conclusion that such a rule would be prohibitively expensive; establishing emission standards appears more likely.

A second type of institutional change would be to use financial inducements to achieve some sort of equity. A governmental body could tax polluters or give subsidies to a firm not to emit pollutants.

A third method is some sort of direct bargaining between sufferers and offenders. In the Polk County case, for example, the citrus farmers and cattle producers could decide to get together to pay the fertilizer manufacturers not to pollute. This would be very difficult to do, however, because of the number of firms involved.

Direct bargaining would be made much easier by fundamental changes in property rights to the air mass. Should the fertilizer manufacturers own the air rights, for example, they would find that they had an important market in addition to that for fertilizers. They could sell air on the basis of the level of fluoride residuals. The decisions on the types and methods of manufacturing would have to take into account not only the cost of producing fertilizer and the profits but also the potential profits from selling clean air. Alternatively, the citrus growers and cattlemen could own the air rights. They would find the fertilizer manufacturers willing to purchase some of the rights in order to release some fluoride into the air. Theoretically, the same economic optimum solution in the use of the air mass would be achieved with either group owning the air rights.

As a matter of fact, the same result could be achieved no matter who owns the air rights. For example, the air rights might be given to me and I would match the bids for various levels of fluoride residuals from both parties. Maximizing my income through market forces would lead to the same economic optimum for the polluters and the polluted, with the difference that my income would go up a great deal. Problems of equity abound with changes in property rights.

It is my intention that these brief sketches of alternatives will whet your appetite for further inquiry. As Crocker and Rogers point out, many people are far too ready to accept rather shallow statements of the causes of environmental deterioration. They too often view the essence of the problem as the presence of residuals in the biosphere. Sometimes, in a more perceptive manner, they view the problem as the escape of residuals from sewers and smokestacks. The escape of residuals is only a symptom of an underlying cause of environmental deterioration. They are symptoms of the behavior of our society as governed by the institutional rules of the game. If the sewer is viewed as a cause, then the sewer is attacked. This leads to putting control devices on the sewer while overlooking a large number of alternative actions. Such an approach will almost certainly preclude attacking the fundamental cause, which is an absence of rules that make it worthwhile for the offenders and the sufferers to count as their own cost the cost now imposed upon others less directly affected. It is in this area—the need for fundamental changes in our operation rules—that there is considerable opportunity for research.

This presentation has not dealt deeply with the issues raised. If it was successful, it raised many more questions than it answered. Its purpose was to suggest that: (1) agricultural research is not necessarily out of balance, (2) the world does not face the impending doom of having to choose between death from starvation or from residuals in the environment, and (3) we need to look at alternative institutional structures that will lead the polluters and the polluted to count pollution as their own cost.

Council on Environmental Quality-- Its Purpose and Accomplishments

Agricultural experiment stations have long studied the maximizing of environmental factors to produce as much food and fiber as possible. Only recently have we become deeply concerned with how the production of plants and animals may, in turn, affect the environment.

In 1969 staff members of the College of Agriculture prepared a long-range planning report[1] which contained three particularly significant sections related to our current environmental program. These were: (1) a statement that a new system for research administration was needed; (2) a section of how agriculture affects, and is affected by, environmental quality; and (3) a section on the need for a natural resources program. As a result of the recommendations of the long-range report, a new two-dimensional approach to administration was evolved in the College. This new approach is exemplified in the Council on Environmental Quality. The Council was established in April of 1970, evolving from a College environmental science committee.

Since the College of Agriculture, unlike other colleges in the University, is responsible for education, research, and extension, the Council was given the responsibility for developing environmental-quality programs in all three areas. The Council began with the following ideas: (1) that the strengths of the departments had to be maintained; (2) that the staff must develop, evolve, and supervise the projects; (3) that any task group must be able to self-destruct once its goal had been achieved; and (4) that the staff members must maintain their subject-matter integrity and competence. It became immediately obvious that a method of administering and coordinating interdisciplinary-interdepartmental research through the departments was needed so that priorities could be assigned and staff members could be persuaded to participate in the research and so that assistance in seeking funds could be provided.

To accomplish this, a chairman, an administrative coordinator, and the eight task group leaders were chosen and designated as the Council on Environmental Quality. The task group areas were selected because of state needs and the recognized competence and leadership already available in each specific area. Task group members were selected from the College, the University, and other outside agencies so that all areas of expertise were represented.

Each task group has evaluated the problems in its area, from the standpoint of both work already under way and research needs at the national and state level, particularly the latter. This stage of development culminated at last year's Allerton Conference. After the conference, the task groups were asked to develop master projects for the Agricultural Experiment Station in areas where major efforts were planned. Because of the multiplicity of their subjects, two task groups have prepared more than one master project. Some of the task groups have developed and implemented their programs; others have finalized their master projects and are just beginning program development; and still others are at the point of analyzing the problems, approaches, priorities, or methodologies. Each task group will report its accomplishments to date.

The achievements are impressive; much has been accomplished in a short period of time. These achievements are an excellent example of how scientists can redirect their efforts. Since not all of their efforts will be covered in the reports to follow, let me summarize the status of each group.

Pesticides and Pest Control Systems. Dr. Metcalf will report on the analogs of DDT that his research group has developed and will display a model ecosystem. The task group is developing a master project that will emphasize three areas: (1) the movement of all types of pesticides in the aquatic ecosystem, (2) development of a model terrestrial ecosystem, and (3) a coordinated attack on the corn rootworm.

Animal and Human Metabolic Wastes. This group is concentrating its effort in two areas. The first is to obtain a better understanding of the aerobic and anaerobic decomposition of animal wastes so that more complete animal waste systems can be developed. Secondly, they are developing a master project to study the problems of strip-mine reclamation. This study will go all the way from the economics of strip-mining and its effects to the chemistry of the spoils.

Erosion and Sedimentation. This group is just completing its master project and has begun a project on conservation tillage.

Wood-Residue and Food-Processing Wastes. The wood-residue program has been under way for two or more years and has already found solutions to a number of problems. Results of this research are being extensively used. The group is now planning to expand and make its study more comprehensive. The food-processing waste group is now developing a master project.

Plant Nutrients. This is the largest effort undertaken to date by the Council. It has involved preparation of a research proposal requesting major funding from the Rockefeller Foundation and preparation of master proj-

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[1] *The University of Illinois and the College of Agriculture, 1971-1968.* A Long-Range Planning Report of the College of Agriculture, University of Illinois at Urbana-Champaign. September, 1969.

Remarks by R. J. Miller, Associate Director, Illinois Agricultural Experiment Station, College of Agriculture, University of Illinois at Urbana-Champaign, and Coordinator, College of Agriculture Environmental Quality Council.

ects for the Illinois Agricultural Experiment Station. Research that has been in progress for more than a year will be reported at this conference.

Extension Education. As a result of the recommendations of the last Allerton Conference, this group is developing seven slide-script programs in various areas of environmental concern that can be used with non-rural audiences.

Policy Alternatives as Related to Environmental Quality. This task group has initiated effort in two areas. One is the cost to society of limited nitrogen fertilization, and the second is the cost to the farmer of limiting erosion with subsequent sedimentation in a reservoir.

Human Interaction With the Physical Environment. A master project has not been developed in this area, but a program has been developed to help people understand why the physical environment is important. This is being done with a film, a narrated slide set, and a work-guide manual. The task group is developing a master project in the area of how people respond to their near environment.

Social Assessment and Rural Development. This task group has just been formed and as yet has no master project. Nevertheless, it is active and has a project studying why some local governments respond more to social change and need than do others. A second project on how people respond to a highly publicized environmental problem is being developed.

The Council and its task groups have been busy. I hope as much progress will be made in 1972 as has been in 1971. Your suggestions and comments have been most helpful, and we hope you will continue to share your ideas and concerns with us as you have in the past.

Pesticides and Pest Control Systems

Total impact of pesticides on the environment is a very important field of interdisciplinary research and has critical importance to agriculture. I think that with the new facilities that are being built on the Urbana campus and with the Natural History Survey working in cooperation with the Illinois Agricultural Experiment Station, we have the possibility of making progress second to none in the whole United States and probably in the entire world in this very difficult field.

Clearly there is no more controversial aspect of agriculture than the impact of pesticides on the environment. You can witness this by reading the newspaper every night because scarcely a day passes without some comment about the impact of pesticides on environmental quality. I do not believe any reasonable or informed person believes that agriculture can attempt the task of feeding the world if it does not have a whole array of modern pesticides at its beck and command. Perhaps one of the best evidences of the general concern about this problem has been the support of the Rockefeller Foundation. The Foundation has done probably more in providing for the health and the feeding of the world through the years than any other single private agency. About three years ago, it organized among four American universities a cooperative program, in which the University of Illinois participates, on the development of selective and biodegradable pesticides. This has given impetus to the work that I want to briefly tell you about. Our prime concern is, of course, that through all the "green revolution" and introduction of new varieties of crops which have done so much to alleviate the hunger and suffering abroad, has run the threat that pests like these new varieties just about as well as humans do. The IR-8 strain of rice developed at the Phillipine Rice Institute, which Rockefeller and Ford support, requires an application of a pesticide about every two weeks to protect it from insects and to produce its full yield. The same thing is true of many of the other crop revolutions that are taking place. Rockefeller, too, has been concerned that the adverse publicity about pesticides, which is not entirely unwarranted because the present ones have a good many defects as well as many virtues, might so prejudice the world that production of pesticides would fall off and farmers would be unable to protect these food crops. They think that the people who manufacture pesticides need a "shot in the arm" and that was the reason behind the organization of this project which they hoped would provide stimulus and ideas for industry.

One of the real concerns about pesticides is, of course, the very large area of the environment that is treated with them. The increasing sales and utilization of pesticides in the United States over the past six years are rather striking. Herbicides, for example, are increasing in utilization about 20 percent per year, and insecticides are not far behind. The sales are enormous, about a billion dollars per year in 1969. It is note-worthy how much of the total agricultural environment of the United States is treated with these materials. In Illinois, from figures that the Department of Agronomy has given me, it is estimated that 43 percent of the agricultural land is treated with herbicides and 33 percent is treated with insecticides. This is excellent as far as crop production is concerned. It helps the growth of the agricultural industry and the pesticide industry, but it does

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Paper prepared by R. L. Metcalf, head, Department of Zoology, University of Illinois at Urbana-Champaign, for the task group on pesticides and pest control systems: W. H. Luckmann, leader, B. J. Butler, H. J. Hopen, R. L. Metcalf, H. B. Petty, J. B. Sinclair, and F. W. Slife.

give one concern about the very large extent of purposeful environmental contamination. At some point critical areas of the environment are going to be oversaturated with pesticides. Another part of the problem is the large number of individual chemical compounds that are being used. Something like 900 distinct chemicals are encompassed in the word pesticides. We do not know nearly as much as we should about all of them. A good many of them are already obsolete or obsolecent, like DDT, and we need, badly, new ones to take their place.

There is one unique thing about the use of pesticides that a lot of people do not understand. We do a lot of accidental contamination of the environment. The housewife with her automatic washing machine surely does not intend to contaminate the Sangamon River and Lake Michigan with detergents, although she does so accidently. But when we use pesticides and fertilizers, we have a totally different objective in mind. They are purposely applied to the environment with the thought that the cost/benefit ratio is certainly far tilted in the direction of the benefit from the use of pesticides over damage to the environment. I think people in agriculture ought to be absolutely sure that when we do this sort of purposeful contamination, we are able to defend it in terms of the good far outweighing the bad. Deliberate contamination, I hardly need to point out, can be the most pernicious of all these kinds of pollution.

Pesticides are microchemical pollutants or ones that exert their pollution effects in the environment at very low levels, say one part per million or less, and I can define this by saying that when you apply one pound of pesticide per acre to the upper 6 inches of soil, you have a contamination of about ¼ part per million. These chemical compounds would not be effective pesticides if they did not have a high physiological specificity to their target organisms, and generally this results in high ecological specificity. The persistent pesticides, of course, are resistant to biochemical degradation in the environment or they would not be highly persistent pesticides. To our amazement, however, over the years they have been found to exhibit alarming properties. They appear at particular points in the food chain, often in highly concentrated levels.

Often we do not find out about this pollution until it has been in the environment for quite awhile. The story of DDT is a noteworthy one. It was not until 15 years after DDT was used on a large scale that we began to be aware of its properties as a microchemical pollutant.

DDT has been singled out as the substance that has probably done more good for humanity than any other chemical that man has ever invented. There are millions of people alive in the world today who owe their lives to DDT. There are hundreds of millions of people who have had illnesses averted by the use of DDT. At the same time, it is so persistent and partitions so strongly in favor of fats that it has become the ubiquitious environmental pollutant. DDT is very soluble in fats but extremely insoluble in water. Furthermore, its chief degradation product, DDE, is even more stable than DDT and causes most of the environmental mischief.

When these substances get into water, and pollution of water seems to be the end result of all kinds of environmental contamination of pesticides, you get the sort of situation that has been described in Lake Michigan. There is very little DDT in Lake Michigan, only about two parts per trillion. That is an almost inconceivably small amount. We used to think nothing could happen if we diluted a pollutant this much, but unfortunately in the mud at the bottom of the lake there are about 14 parts per billion. The fairy shrimp or amphropods, which are a large source of food for fish in the lake, are able to accumulate the DDT to 400 parts per billion. The Coho salmon and the lake trout, which are very important game fish, as well as other fish in the lake, accumulated another tenfold or so, so that they actually have three to ten parts per million in their bodies. When birds, like the herring gulls, feed on these fish they accumulate another tenfold concentration, so that if we fed on a diet of herring gulls, we might be seriously in danger of having 1,000 parts per million of DDT in our bodies. This situation represents a typical food-chain accumulation or ecological magnification of about ten million times from the concentration in the water to the concentration in the birds. Perhaps the worst thing about it is that for many organisms this kind of accumulation is virtually irreversible and goes on over the lifetime. Experiments that we have carried out in cooperation with the Illinois Natural History Survey have shown that fish in water containing ten parts per billion of DDT accumulate it in direct proportion to the time they remain in the contaminated water, so it is not wise, if you want to avoid eating environmental pollutants, to eat large old fish.

To come to grips with this sort of situation we had to have some sort of experimental model. You perhaps have seen the exhibit we have prepared of our model ecosystem. This work was actually started five years ago at the University of California, and it has taken us a long time to arrive at our present model, which seems to us a rather sophisticated situation although it may not look so to you. Our model ecosystem is a small aquarium which has a terrestrial farm where we grow sorghum plants. Caterpillars feed on these, and we apply the radioactively labeled pesticides to the sorghum at the rate of approximately one pound per acre based on the land area of the ecosystem. The whole thing is built out of pure washed white sand. We can trace how this labeled pesticide, whatever it is, moves from the land, just as it moves on the farm and drains into a farm pond or into Lake Michigan. The lake in the model ecosystem has a representative collection of food-chain organisms starting with microbes and plankton of all descriptions, working up to water fleas, mosquito larvae, and finally to little larvivorous fish. We use a fish called "gambusia" because it loves to eat mosquito larvae, and that completes our food chain. When we get through with this, we can take the whole thing apart and by radiochemical techniques follow what happens to the labeled pesticides. We have looked at about 30 pesticidal compounds of all descriptions now, and this is becoming an extremely popular thing with regulatory agencies such as the EPA and the World Health Organization, which is concerned with proving the environmental safety of new pesticides proposed for the control of vectors of human diseases. For the first time we think we have a system which is like a laboratory rat or rabbit, in a way, in which you can determine in rather exhaustive detail just what is happening in a little segment of the environment. It is obviously impossible to do this in Lake Michigan very quickly for example. If 20 years ago we had had the data we have from this model ecosystem about DDT, perhaps we would not be in the mess with DDT in the environment today.

The food web that takes place in this system ranges from the sorghum plant through the caterpillar into the water, then through an algum to the Physa snails, and through the elements of the plankton into the mosquitoes and into the fish. So we can actually account for a seven-step transfer of the active material of the pesticide into the final product of the fish. This is primarily useful in evaluating new compounds that industry proposes to use as pesticides to see if they get a clean bill of environmental health.

The problem with DDT in living organisms is that it is not very degradable, although you can find several different chemical compounds—DDE, DDD, and DDA—produced from DDT in the environment. Most of the DDT goes to DDE, by loss of one chlorine and the introduction of a double bond, and slowly some of it goes to DDD and eventually DDA. This process occurs in all kinds of organisms with different rates, even in man. Every year half of the DDT we have in our bodies, averaging about five parts per million in our body fat, goes through this system and comes out as DDA, which is water soluble and is eliminated in the urine. The trouble is that this process is not fast enough, and some of the DDT escapes and is stored in body fat.

When we evaluated DDT in the model ecosystem, we found that the fish accumulated about 19 parts per million of DDT and had even higher amounts of DDE. The ecological magnification from water to fish was 84,000 times.

What do we have to work with in trying to design persistent, biodegradable substitutes for DDT? In all living animals there is a group of enzymes called the multi-function oxidases. These are the "drug metabolizing" enzymes. They are there from evolutionary causes to enable us to get rid of foreign molecules that we take into our bodies. They probably evolved because not everything that an organism eats is necessarily nutritious and there is need to convert foreign fat-soluble molecules into water-soluble molecules. So these enzymes take air and convert it into an active hydroxylating intermediate with which they can do a great variety of chemical reactions. Now higher animals have these concentrated in the livers, and when you eat something, even a residue of DDT, the blood passes it rather rapidly to the liver and the liver tries to get rid of it, to eliminate it through your kidneys and out into the environment again. Insects do not have nearly as much of these enzymes as warm-blooded animals, and furthermore they do not have livers. If we can produce pesticide compounds particularly tailored to the tastes of these mixed-function oxidase enzymes in higher animals, then possibly we can use them as pesticides against lower animals and plants with some success. So this is really our *modus operandi* in trying to develop biodegradable DDTs.

We started with the compound methoxychlor, which was discovered about 1893 and has been used as an insecticide for 25 years. It is known that although methoxychlor has chemical properties like DDT, it does not behave like DDT in the environment. When you feed it to animals, it is not concentrated in fat. So we thought first we ought to find out why. We found that these multi-function oxidases in higher animals rapidly take these methoxy groups off methoxychlor and convert it to water-soluble phenols. These instead of going to the fat pass through the kidneys and are excreted.

By using radioactively labeled methoxychlor, we were able to test out this process in the model ecosystem. We found those postulated hydroxlated products, and we did not find much accumulation of methoxychlor in the fish. Nothing at all, compared with DDT.

Another possible handle we could use on the DDT molecule is putting methyl groups in place of the aromatic chlorines. We found these too can rapidly be broken down by the mixed-function oxidases to form carboxylic acid groups, and we end up with a benzoic acid type of derivative, which again is water soluble and is excreted rather than stored. In the model ecosystem we did not find any of this compound in fish. We found some of it in the algae and traces in the mosquitoes and snails, but we also found these water-solubizing carboxylic groups in water of the ecosystem, thus proving that the compound is biodegradable.

We looked at all the ways we could put handles on the DDT-type molecule which would make it particularly susceptible to attack by these multi-function oxidases. The methio group is another group which can be oxidized to sulfoxide and sulfore and this makes it more water-partitioning. The net result, of course, is that it can be excreted too. We found none of the parent compound in the fish and a little bit of some of these oxidation products. But again this kind of molecule is quite biodegradable.

To summarize, we have found at least three ways we could alter the DDT molecule and promote biodegradability in a broad sense. These produce the kinds of chemical transformations in living tissues that result in metabolic compounds in all cases that tend to go into the water phase rather than into the fat phase. Therefore, they are excreted from the bodies of animals and do not concentrate in fatty tissues.

This is not the whole story. About all we really know of the action of DDT, despite the production of billions of pounds and 25 years of very intensive study, is that it acts as a molecular wedge and somehow finds its way into the nervous system of either an insect or higher animal where it begins to distort nerve-impulse transmission because of its adsorbability at the interface of the lipoprotein strands of the nerve action. It pushes these apart and causes ion leaks which disturb nerve-impulse transmission. This is what gives rise to the symptoms within a fly or insect that we often call the DDTs. This is obviously associated with the very specific molecular geometry. It does not do us much good to try to invent biodegradable DDT derivatives by putting all sorts of groups on the molecule which promote elimination, if we somehow lose this DDT-type action on the insect. What we are actually doing here is playing a three dimensional kind of chess with our molecules. I have a big set of molecular models in my basement study. When I get bored, I try to find new ways to put them together to make DDT-like models. Then we make them in the laboratory to see if they kill insects.

When we began to put two different groups on the DDT rings, to form asymmetrical compounds so that at least one side of the molecule had a handle for the attack of the multi-function oxidases, we found that we had produced effective insecticides that were also substantially biodegradable. Strangely enough, very few of these compounds had ever been made before. The industry settled on DDT as the cheap, highly persistent active compound and never looked for substitutes. We have looked at the toxicity of about 100 of these asymmetrical compounds, and there are a number which are highly toxic to insects.

It is interesting to note, of course, what these do to warm-blooded animals. One of the first things we looked at was their toxicity to mice. Most of the compounds were so nontoxic to mice that we could not affect them with 1,000 micrograms per gram. In other words, they are ten or more times less toxic than DDT. DDT is not a very toxic molecule to higher animals. In all the time people have been using DDT, nobody has ever been killed by it. With the new compounds we have an enormous margin of safety. There is only one compound with ethoxy, propoxy substitution, which is more toxic than DDT. We can account for this biochemically because enzymes are not able to decompose these longer chain groups very rapidly. So this compound actually seems to be a better molecular wedge for mice at least than DDT. We want to stay away from it.

Finally, what happens to these new compounds in the model ecosystem? One of our better compounds has a methothio group on one side and a methoxy on the other, thus having two distinctly different ways in which these multi-function oxidase enzymes could take it apart. You can see we found a very large variety of altered compounds in the water of the model ecosystem. We found that there was almost no accumulation of any of these in fish, and this is a highly biodegradable compound as compared with DDT. It is also a fairly good insecticide.

Another way of doing the same thing is with two different groups acted on in two different ways with a methyl group on one side and ethoxy on the other. Here again, the fish got a pretty clean bill of health, as far as the accumulation of anything in them is concerned, as did the other organisms. The snails are one of the great anomalies. They seem to act like great big blotters. If you want to find out what is in anybody's water, you just want to put a bag of snails in there and leave it for a few days and analyze it later. We have found that snails can accumulate almost any of the common chemicals. They do not have much of these multi-function oxidase enzymes to enable them to get rid of these foreign compounds.

Finally, now that we begin to look at this in a quantitative way, we have proposed a function called the "biodegradability index" which simply means the polar material or the material that is water soluble, divided by the non-polar or fat-soluble material. We can determine this very easily from thin-layer chromatograms with the radioactively labeled compounds. All the spots that move up with the solvent, as you develop the chromatogram, are non-polar if we use a non-polar solvent like hexane. The ones that stay at the bottom are polar. So we merely need to count all the radioactivity in the various spots and add it up to determine the "biodegradability index." We set it up this way so the DDT, which is not very biodegradable would have a very low index—about 0.01. Some of the better compounds which are degraded would have high indexes. There is an enormous difference between compounds with a high "biodegradability index" and DDT and DDE. Another way of looking at it is ecological magnification in the fish, which is the amount of the material in the fish for the parent compound divided by the same amount of that material in the water. These two parameters give us a pretty good idea of how any new compound is going to behave. That is what the World Health Organization has tentatively proposed we should use as our ultimate criterion after having gone through our study of the model ecosystem.

What does all this add up to? It is obvious that people are going to classify pesticides as to how they react in the environment. The Mrak Committee has proposed an influential classification which has four grades. With grade one, which has no significant contamination, you will note that contamination is put first along with hazard to the user or other people, and with grade four there is severe contamination. Nonessential use is likely to be restricted by law, and the material will require permit and perhaps be removed from the market. DDT falls in grade four. There are very many pesticides like malathion and carbaryl and most of the common herbicides that do not seem to offer any particular risk, and they are in grade one. It is going to take a good bit of information about many pesticides to find out exactly where they fall. We think the model ecosystem is logically the first step in beginning to grade pesticides. Obviously anyone who manufactures a compound with environmental properties like DDT, when we have concrete evidence of what is going to happen, is taking a very big chance indeed. So we can save a lot of false steps and effort.

And finally, how do we use these better pesticides once we have them? That is what our task force, I think, is most interested in. These are some of the points to be observed. You will note that the emphasis is on pest management control programs where we can use the least amount of pesticides necessary to do the job, and use the pesticide in the most precise manner. We like to think of this use of pesticides as a sharp scalpel or foil, rather than an ax or broadsword. I am afraid that in the past we have not always looked at it that way. Certainly, observing the economic threshhold, that is, the level at which it pays you economically to use a pesticide and not treating before there is some damage, is one way to minimize pesticide use. We want to use pesticides to minimize damage to the environment, to the biological control agents that are present, and also to use cultural methods to the greatest advantage. Some thought has to be given to the philosophy of preventive treatments. People treat whether they have a problem or not, under the assumption they are likely to. This, of course, means more contamination in the environment than is necessary. There must be great emphasis on putting the pesticide in its proper place. It used to be that you thought you could fly an airplane over your farm and dust, or spray, without anything happening to your neighbor. It was not until cotton died 20 miles from where weeds were sprayed with 2,4-D that we began to be aware that environmental hazards could be serious. Pesticides do not stay where they are put. We must find better ways, either to bring the pest to the pesticide or put the pesticide very precisely in place and hope to keep it there.

To conclude, we are going to need a whole new array of selective and biodegradable pesticides.

Animal and Human Metabolic Wastes

This task group is mainly concerned with the management and utilization of livestock metabolic wastes and the residues from treatment plants for human metabolic wastes. Land, not water, is considered the final disposal site for surplus products from both the above sources of metabolic wastes. The research emphases, however, are on utilization of misplaced resources rather than on waste disposal.

Objectives of this task group are:

(1) To manage livestock wastes for minimum adverse effects on the quality of the environment and for maximum economic returns to the livestock enterprise;
(2) To utilize the end-products of sewage treatment facilities for plant nutrients and soil reclamation;
(3) To use land effectively in waste disposal and utilization systems;
(4) To identify potential environmental hazards and study corrective methods of control; and
(5) To assess the economic, social, and environmental aspects of alternative systems of disposal of animal and human metabolic wastes.

For further details, refer to the task group's Master Plan for Research. Also; refer to last year's conference proceedings for an introduction and background to the overall problem. A progress report since last year's conference follows.

Livestock Wastes

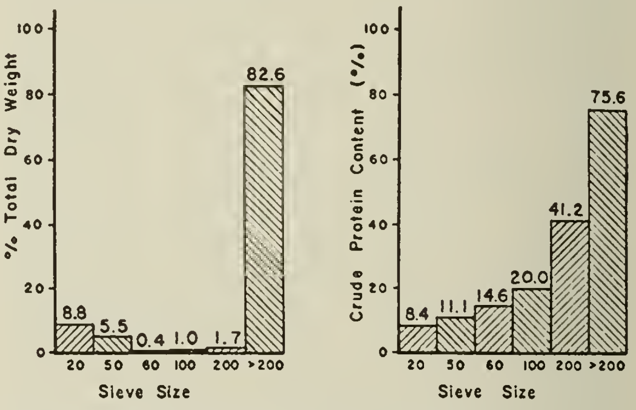
Concentration of Proteinaceous Solids From Aerated Swine Manure

The objectives of this study were to determine what portion of swine oxidation ditch mixed liquor (ODML) contained proteinaceous material with a refeeding potential and the feasibility of recovery and concentration of this proteinaceous portion.

Swine ODML samples were passed through a series of sieves ranging in size from 20 mesh down to 200 mesh. The solids retained on each screen were dried, weighed, and analyzed for Kjeldahl nitrogen. Typical results of these tests are shown in the following figures. Note the important discovery that 83 percent (dwb) of the swine ODML suspended solids (S.S.) passed through the 200-mesh screen and that this same size fraction contained up to 75.6 percent (dwb) crude protein (Kjeldahl nitrogen x 6.25). The next largest weight fraction was that retained on the 20-mesh screen, but it was comprised primarily of hog hair and corn kernel hulls and contained only 8.4 percent crude protein.

From these tests, it was concluded that the material of interest for refeeding was the smallest size (that passing through the 200-mesh sieve). Investigations were then made to recover and concentrate this fraction.

Centrifugation trials were made. Prior to centrifugation, the swine ODML samples were passed through a 20-mesh screen to remove hog hair and corn kernel hulls. Laboratory batch-type and continuous-liquid-phase centrifuges were tested. Also, a 14-inch solid-bowl basket pilot plant centrifuge was tested. The concentrated cake was analyzed for amino acids, typical values of which are given in the following table. Centrifugation was shown to be a feasible method of concentrating the amino acid-rich portion of swine ODML. Liquid volume reductions in the order of 85 percent were achieved while increasing the solids content of ODML from 1.2 to 8 percent. This solids concentration is sufficient to enable researchers to refeed a substantial amount without including the bulk of the carrier liquid. *(Investigators: L. W. J. Holmes, D. L. Day, B. G. Harmon, J. T. Pfeffer)*



At left, sieve size analysis of swine ODML. At right, crude protein analysis of suspended solids retained on each sieve size.

Nutritive Value of Processed Swine Waste

The products of aerobic swine waste digestion are being evaluated as nutrient sources, specifically amino acid sources. Lysine, the first limiting amino acid in corn, is being used as an indication of amino acid quality. The oxidation ditch mixed liquor (ODML) typically contains 1.42 percent lysine (expressed as percent of dry matter). Fractionating the solids from the ODML through sieves, as described by Holmes, the lysine increases as sieve size decreases as follows: the 20-mesh fraction is 0.38 percent lysine; 50 mesh, 0.92 percent lysine; 100 mesh, 1.36 percent lysine, and more than 200 mesh, 3.83 percent lysine. Samples of aerobic waste from the Urbana, Illinois, municipal waste treatment plant were analyzed and found

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Report of the task group on animal and human metabolic wastes: D. L. Day, leader, O. C. Braids for S. W. Melsted, M. P. Bryant, B. G. Harmon for A. H. Jensen, A. J. Muehling, J. T. Pfeffer, and G. T. Woods.

Table 1. Typical Amino Acid Analysis of Swine ODML and of Corn and Soybean Meal

	Swine ODML	Corn	Soybean meal
*Lysine	1.42	.27	3.10
*Histidine	.47	.25	1.23
*Arginine	1.28	.38	3.58
Aspartic acid	3.73	.56	5.51
*Threonine	1.96	.32	1.91
Serine	2.55	.41	2.49
Glutamic acid	5.06	1.47	8.08
Proline	1.29	.74	2.32
Glycine	2.29	.30	2.04
Alanine	2.83	.63	2.05
Cystine	.41	.14	.40
*Valine	2.06	.41	2.43
*Methionine	.77	.17	.60
*Isoleucine	1.49	.27	2.22
*Leucine	2.79	1.02	3.59
Tyrosine	1.17	.37	1.75
*Phenylalanine	1.48	.42	2.37

*Essential amino acid.
Note: All values are in percent of oven-dried weight.

to contain 1.35 percent lysine in the dry matter, almost the same value as for swine oxidation ditch mixed liquor.

Finishing swine have been fed a corn soybean meal diet with 2 parts of water or 2 parts of oxidation ditch mixed liquor added per part of dry feed. The treated pigs did not gain significantly more rapidly or efficiently but values were always greater for the treated pigs. Rats were fed diets equal in lysine with 0, 4, 8, and 12 percent of the diet as freeze-dried ODML. Weight gain and efficiency were reduced for rats receiving the higher levels of ODML, but nitrogen retention was similar for all groups. Energy digestibility decreased with increasing levels of ODML. *(Investigators: B. G. Harmon, A. H. Jensen, D. H. Baker, D. L. Day)*

Mosquito Control and Fish Production in Livestock Waste Ponds

Ten livestock waste ponds (swine, cattle, and sheep) are present on the south campus area of the University of Illinois. Tremendously large populations of mosquito larvae and pupae occur in these ponds between mid-July and mid-October. At least one of the dominant mosquito species constitutes a public health hazard because it is a vector for human encephalitis. In order to control the mosquito populations during the summer of 1971, it was necessary to treat the ponds with fenthion (baytex) at two-week intervals. When the water level in one pond was lowered below the shoreline vegetation, the numbers of mosquito larvae and pupae were drastically reduced. However, it is very difficult to control the water levels in these ponds.

The following physical factors were monitored at two-week intervals in the three largest lagoons: pH, temperature, light penetration, turbidity, dissolved oxygen, sulfate, nitrate, nitrite, ammonia, phosphate, alkalinity, hardness, chemical oxygen demand, biochemical oxygen demand, and conductivity. In these three largest lagoons the dissolved oxygen reached super-saturated levels during the day. In two of these lagoons the dissolved oxygen fell to zero during the night, but in the third it usually did not fall below 2 p.p.m. Several species of fishes placed in cages in this third pond were able to survive for several weeks.

Aeration equipment is being installed in two ponds so fish might be maintained in them. Since these ponds are very rich in nutrients, fish production should be extremely high. Many species of warm water fishes feed voraciously on mosquito larvae, so if fish could be reared in these ponds the mosquito health hazard problem would be eliminated. *(Investigators: J. A. Tranquilli, W. F. Childers, G. W. Bennett)*

Effects of Manure Gases on Swine

A project involving collaboration among personnel from the Animal Science and Agricultural Engineering Departments and the College of Veterinary Medicine has been initiated to study effects of certain air-environmental factors on swine. Its objectives are to determine maximal levels of atmospheric NH_3, H_2S, and CO_2—singly and in combinations—compatible with long term performance of swine in terms or rates of voluntary feed intake and gain as well as feed-conversion efficiency; to determine residual effects on performance due to short term exposure to high levels of the gases; to determine long term and short term effects of the gases on bactericidal capability of lungs; and to determine whether practically encountered levels of NH_3 cause a net uptake of NH_3 across respiratory membranes and, if so, whether this can contribute to the metabolic pool of nonspecific nitrogen. At present (September, 1971), equipment and instrumentation are being assembled. Experimental trials should begin the first part of 1972. *(Investigators: S. E. Curtis, A. H. Jensen, J. Simon, D. L. Day)*

Economic Effects of Alternative Environmental Policies on Cost of Pork Production

Suburban development and continued increases in livestock density have combined to magnify public awareness of the problems associated with animal manure disposal. In addition, methods of handling wastes are being closely scrutinized as to their possible adverse effects on air, water, and soil quality, and on the sensitivities of those who live near livestock operations.

Possible consequences stemming from recent environmental quality legislation suggest a potential need for production adjustments. Livestock producers are interested in waste treatment and disposal methods that have low labor requirements, reduce nuisance conditions, and improve sanitation at minimum cost. However, the magnitude of this cost for various alternative production systems remains a critical question to be dealt with in the evaluation of an environmental protection policy.

The economic effects stemming from alternative environmental policies on producers who have varying types and sizes of operations may range from none to economically forcing the producer out of production. The focus of this research effort is therefore to systematically utilize available concepts and data in order to examine alternatives with respect to their effects on production efficiency and their potential effect on environmental quality.

The objectives of this project are:

1. To classify hog production systems according to size of operation and housing facilities.

2. To describe waste handling methods and determine their cost and their potential degree of pollution control.
3. To evaluate the economic consequences of various pollution abatement practices available to the swine producer.
4. To evaluate the effect on the hog producer of alternative regulatory instruments designed to achieve acceptable environmental quality control.

(Investigators: J. C. Gamble, R. N. Van Arsdall, E. R. Swanson)

Refeeding of Sheep Wastes

Research on waste handling and recycling by those interested in ruminant research dates back several years. Initial studies were related to the survival of virus in sewage sludge fermentations. Since this early work, more applied interests have developed dealing with the influence of ration composition on the nutritive value of sheep feces. Given that sheep and other ruminants consume diets varying widely in composition and digestibility, it is reasonable that marked differences may exist in the nutritive value of the fecal material and urine voided. It is also possible that method of storage (as silage or with silage) may influence acceptability of diets containing fecal material. To date laboratory studies suggest wide variations in nutritive value with the lowest values for residues from animals fed all-roughage diets and increased value as level of concentrate in the diet increases. Fecal material from lambs fed all-concentrate diets is, when dried, only slightly below oats in estimated nutritive value for ruminants. Fecal material ensiled with chopped, whole corn plant (1:1 on fresh basis) appeared to be as acceptable to adult sheep as regular corn silage when fed as 0 to 50 percent of their daily ration. In these studies, the sheep consumed as much as 25 percent of their daily ration as fecal material; higher levels were not studied. When nitrogen balance studies are used with lambs, it is apparent that only part of the nitrogen in fecal material is available for use by the ruminant.

Research in the immediate future will obtain animal values similar to the previously mentioned laboratory values using both nitrogen balance, digestion, and growth studies. Also available at the Dixon Springs Agricultural Center is a new slotted-floor sheep unit with an 8-foot basement (the overall dimensions are 120 x 32 feet of slotted floor). This structure offers the opportunity to study various methods of manure handling. Presently, the fecal material is quickly removed with a tractor-loader and blade. Some of the manure is being dried in the homemade batch drier for use in the previously described research. *(Investigators: G. E. Cooper, F. C. Hinds, J. M. Lewis)*

Liquid Digested Sewage Sludge Disposal on Land

Research on the land disposal of liquid digested sewage sludge has been conducted at the Northeast Agronomy Research Center in Elwood, Illinois, the site of a large instrumented lysimeter facility, and at the small field lysimeter facility on the Agronomy South Farm. At the Research Center three supplementary experimental fields have been cropped with corn, soybeans, alfalfa, and kenaf (a fiber crop). Table 2 compares sample corn yields from fields treated with sewage sludge with those from fields treated with relatively high per acre rates of inorganic fertilizer. Sludge irrigation even at the lowest rate produces yields equal to or better than inorganic fertilization alone.

Table 2. Continuous Corn Yields Obtained With Sludge Treatments[a]

	Rate of application of sludge				Total liquid, in./yr.
	0 in.[b]	¼ in.	½ in.	1 in.	
	bushels per acre				
					6.75
1968	66.3	96.2	114.2	11.9	6.75
1969	142.8	149.0	150.2	150.6	10.0
1970	87.8	119.4	121.5	137.0	9.0

[a] Hinesly, T. D., and R. L. Judson, Illinois Fertilizer Dealers Clinics, 1971.

[b] Received 240 pounds of N, 272 pounds of P_2O_5, and 240 pounds of K_2O per acre.

Limited data on runoff and drain water from the lysimeters show that in drain water nitrate losses, but not ammonium or phosphate losses, are positively correlated to sludge application rate. In runoff water ammonium is negatively correlated and phosphate is positively correlated with sludge application rate. Heavy metals are negligible in water from both sources.

The lysimeters on the Agronomy South Farm have been cropped and irrigated with digested sludge since 1967, a total of 42 inches of liquid sludge having been applied at the maximum rate. Corn, grain sorghum, soybeans, and reed canary grass were grown; the crops were chemically analyzed and their yields were recorded. Soils and drainage water samples were also analyzed for macro- and micronutrients.

From the extensive data from these experiments, the uptake of trace metals in corn leaves and grain is shown in Table 3; these data are meant to be regarded as representative of all the grain crops tested. All the grain crops had similar relationships of metal uptake to sludge application rate and of leaf to grain tissue metal concentrations.

Soil analysis showed that heavy metals accumulated with sludge irrigation, but none were shown to move outside the zone of cultivation; that is, they are not leached. The accumulation of organic matter produced noticeable improvement in the soil's physical characteristics.

Our studies have resulted in the following conclusions:

1. The fecal coliform population in sludge decreases by 99.9 percent within 30 days after being placed in storage or applied to soil.
2. Nitrogen in digested sludge is the most immediate limiting factor to rates of application on field crops. About one to two inches would satisfy the nitrogen requirement of nonleguminous crops without producing excessive nitrate in percolaged water.
3. Heavy metals are a ubiquitous constituent of solids digested sludge; after application to soil they remain in the plow-layer. The plant uptake of Zn, Mn, and Fe has generally been enhanced by sludge application; studies indicate that this is from mobilization of native supplies.
4. Digested sludge has been shown to be an effective source of nitrogen, phosphorus, and micronutrients. Crop response to the water included in sludge application has also been observed.

5. Salt accumulation in humid region soils should not be a problem.
6. Properly digested sludge produces no offensive odor after soil application.
7. Liquid digested sludge should not be sprayed directly on a growing crop unless done very infrequently. Sludge sticking to leaves decreases yields noticeably.

(Investigators: O. C. Braids, T. D. Hinesly, R. L. Jones)

Table 3. Composition of Corn Leaves and Grain From the South Farm Lysimeters, 1970[a]

Total accumulated sludge application, inches	Trace metal concentration, p.p.m.					
	Zn	B	Fe	Mn	Al	Cu
			Leaf			
35	663	19.5	114	219	78.5	18.2
17.5	563	17.6	104	162	76.0	18.8
0	396	16.8	152	164	79.5	16.8
			Grain			
35	222	4.5	88	9	<10	8.9
17.5	179	6.6	103	11	<10	11.5
0	134	4.2	57	8	<10	7.3

[a] O. C. Braids, unpublished data.

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Strip Mine Reclamation With Anaerobically Digested Sewage Sludge

On the basis of small-scale tests by the Shawnee National Forest, the use of anaerobically digested sewage sludge appears to hold some promise in the reclamation of acid spoils from strip mines in southern Illinois. This report is concerned with the results of pilot tests and plans for application of sludge on a much larger scale.

About 18 months ago we were approached by the Department of Conservation and the Institute for Environmental Quality to see if we could be of some help to the Metropolitan Sanitary District of Greater Chicago in providing disposal sites for the large quantities of digested sludge that had accumulated in their storage lagoons. We pointed out that a large-scale disposal project would not be feasible at present for two main reasons. First, we did not know what the public attitude would be and there had been unfavorable reactions in other parts of the state. Second, there were questions related to the highly acid environment of the proposed disposal site as well as the fate of heavy metals contained in the sludge. However, we expressed an active interest in conducting field tests, and if these were favorable to consider a larger operation. We have proceeded on that basis.

A proposed disposal site, known as the "Palzo Tract," was acquired by the Shawnee National Forest in 1967. The area was strip-mined in 1959-1961, prior to current laws, by the Stonefort Mining Company and about 150 acres are in need of reclamation. Because of the nature of the mining operation, exposed iron pyrite and shale are oxidizing to form sulfuric acid and iron sulfates. The De-Koven and Davis coal seams, which were mined here, are particularly high in sulfite. This, in combination with the sandstone which provides iron pyrite, produces highly acidic water and spoil. Spoil pH ranges from 2 to 3.5. The water is extremely acid at about 20,000 mg./l. as $CaCO_3$ equivalent. High concentrations of iron, aluminum, and manganese are responsible for this highly buffered acid water.

All previous reclamation plans had one thing in common: to stop the pollution of nearby Sugar Creek by the highly acid runoff. In addition to this objective, restoring the land to productivity by utilization of anaerobically digested sludge is also desired. To evaluate the feasibility of this reclamation method, the following demonstration study was initiated.

During November, 1970, liquid sludge was applied to four different 0.125-acre plots at the equivalent rate of 121, 71, 31, and 0 dry tons per acre. The plots were designed to capture subsurface runoff. On March 16, 1971, K-31 fescue and weeping lovegrass were sown on all plots. The K-31 fescue was sown at 20 pounds per acre and the weeping lovegrass at 7 pounds per acre. By May the seed had germinated and was growing well on all but the control plot where there was no germination. By June the plot which received 121 dry tons per acre supported a vigorous grass cover while the other treatments supported progressively less vegetation.

During the third week of June, 1971, the K-31 fescue began to wilt, but weeping lovegrass, a more drouth-tolerant species than fescue, retained its vigor. Root systems of both species were examined and were found growing only in the layer of incorporated sludge. They did not penetrate the underlying acid spoil material which maintained a pH of less than 3, thus indicating that incorporation of the treatment material will be necessary or at least most desirable.

Subsurface leachate from all four of the plots was collected and analyzed for chemical constituents and biological organisms. On the most heavily treated plot, 50 to 90 percent reductions in iron, aluminum, and manganese concentrations were recorded. Similar reductions also occurred for zinc, copper, lead, and sulfate. Although acidity was decreased by 80 percent, it is still high enough to cause pH values of less than 3.0. Tests for coliform bacteria were negative throughout the period.

It is obvious that the sludge treatment has had a favorable effect on the site, both in ameliorating the severe acid conditions and in establishing vegetation which will serve as an erosion-control measure. We are now proposing to expand the study to 200 acres. This will include most of the area contributing acid drainage into Sugar Creek. A public hearing on the proposal will be held on January 15, 1972, and this will largely shape our plans for the future. [The hearing was held as scheduled, and the public reaction was favorable for continuing the project.]

Report by Charles Hendricks, Supervisor, Shawnee National Forest.

Erosion and Sediment Research in the United States

Accelerated soil erosion exerts a great influence on environmental quality in three ways. First, erosion of cropland seriously deteriorates its productivity and farmability. Second, sediment in transport pollutes streams and water supplies, both directly and through unwanted chemicals that it carries. Third, where the sediment finally comes to rest, it covers flood plains, fills lakes and reservoirs, and inflicts other costly damages. The effects of each of the three stages must be directly considered in erosion research and control programs.

Erosion-Research Background

Most of the erosion and sediment research in this country has been, and is being, conducted by the Soil and Water Conservation Research Division of the USDA Agricultural Research Service in cooperation with land-grant universities. Some related studies are sponsored by university graduate schools, the Forest Service, the Department of Interior, the Environmental Protection Agency, and others. Committee SW-223 of the American Society of Agricultural Engineers recently updated a listing of engineering studies in the area of erosion and sediment. In the time allotted, my report can present only a thumbnail sketch of programs and progress.

A recent review of the Agricultural Research Service Activity entitled "Improving Water Erosion Control and Streambank Stabilization" showed 18 scientist man-years budgeted to it, in 15 states. About one-third of these are in the Corn Belt Branch. An unpublished list, by title and state, of 57 specific studies that were active under this ARS Activity early in 1971 can be supplied upon request to our office at Lafayette. In addition to these 57 studies, soil management, gully control, chemical pollution, watershed, and wind-erosion investigations are conducted by the ARS-SWC under other research-activity titles. Annual progress reports are included in a national computerized information retrieval system (CRIS).

Although there were some fundamental laboratory and analytical investigations, most of the erosion-research information prior to 1960 was obtained from plot installations under natural rain. The runoff was caught in tanks, measured, and sampled for soil content. Very few of these installations now remain operative because of prohibitive operational costs and because too many years are required to obtain reliable answers. Rainfall simulators *(1)** are now used in Indiana, Minnesota, Nebraska, Georgia, and New York to apply design rainstorms at the exact time in a rotation cycle that the researchers wish to test. These are speeding up field testing of erosion-control practices and concepts. Also, fundamental studies of the basic principles of erosion have received appreciably more emphasis within the past decade.

Research over the past 40 years has strongly emphasized the likelihood of extremely large inherent variabilities in the results of field-plot studies in different years or at different locations. No matter how carefully soil-loss data are taken, they are difficult to extrapolate to other locations or other situations because of highly important interactions between soil characteristics, rainfall distribution, topographic features, and variations in management practices. Quantitative evaluations of some of the most important interaction effects became possible when, in 1954, the ARS established at Purdue University a national runoff and soil-loss data center. More than a quarter-million soil-loss observations were assembled at the center from the studies conducted since 1930 in 26 states and were transferred to punched cards for overall statistical analyses.

Current Programs and Progress

Erosion Equation. From the assembled data came the empirical erosion equation that is now very widely used to help guide the programs of the 3,000 soil and water conservation districts. The overall analyses and resultant equation made it possible to adjust soil-loss data for effects of differences in soil, weather, topography, and management and thus to extend their usefulness. It also made possible the widespread use of a specified limiting-soil-loss concept to determine which combinations of practices are adequate for each particular situation.

The erosion equation expresses soil loss in tons per acre as a function of six factors. The model is $A = R\ L\ S\ K\ C\ P$. The rainfall-erosion index, R, is a measure of the rainstorm energy and also an approximation of the storm's runoff-producing potential. The length and percent slope factors, L and S, adjust the erosiveness of the runoff to the particular topographic features of the field. The factor K is a measure of the specific soil's susceptibility to detachment and transport by rainfall and the associated runoff. The product of these four factors, R L S K, shows what would be the potential soil loss if the surface were continuously in bare fallow.

The factors C and P then adjust this basic value for the effects of crops, plant residues, tillage practices, contouring, terracing, and other management features which help the soil to resist the erosive forces. Charts and tables of information needed to evaluate each of the six factors for

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*Numerals in parentheses refer to literature cited.

Remarks by W. H. Wischmeier, Research Investigations Leader for Water Erosion, ARS-SWC, and Associate Professor, Department of Agricultural Engineering, Purdue University. Contribution of Corn Belt Branch, ARS, USDA, in cooperation with Purdue University.

a particular farm field were developed from the assembled data and published in USDA Agricultural Handbook No. 282 *(2)*.

Soil-Erodibility Nomograph. Evaluating the soil factor, K, for each of the numerous soils and subsoils has been a major and difficult problem. Very extensive field and laboratory research finally culminated, in 1971, in the derivation of an easily used soil-erodibility nomograph that appears to have largely solved this problem. The information needed to read the value of the soil factor for a given soil or subsoil from the nomograph is available from soil descriptions developed by SCS. Copies of the nomograph *(3)* are available.

Minimum Tillage. In recent years, considerable research has been directed toward evaluation of the effectiveness of the many variations of practices that are usually lumped under the term "minimum tillage." On small watersheds at Coshocton, Ohio, planting corn in chemically killed bluegrass sod, without tillage, is showing phenomenal results, even on a 15 percent slope. Five tons per acre of chopped cornstalks and barnyard manure have also eliminated serious erosion. But minimum tillage doesn't usually involve such dense and complete soil cover. Partial covers are also effective, but significantly less so.

Other forms of reduced tillage are under study on plots under natural rain in Iowa and Missouri. These include use of the practices with soybeans, both continuous and alternated with corn.

In a continuing Indiana study the approach is to identify and evaluate the important components of minimum tillage so that a formula can be derived for evaluation of any particular practice or implement, in relation to soil properties, rainfall pattern, and topography.

Eight variations of the practice were field-tested for several years, using the rainulator. The last year of the study included measurements of the nitrogen and phosphorus losses in runoff associated with different degrees and forms of tillage. The eight minimum-tillage practices tested were very far from being equally effective. They identified important factors that determine the effectiveness of a practice: amount and distribution of surface residue after planting, height of ridging, row direction, amount of loose soil, effect on infiltration, and prior cropping.

Related rainulator studies are evaluating kinds, rates, and distributions of crop-residue mulches in relation to tillage, soil, and topography. Analyses of the data in search of a dependable formula for evaluating specific practices or farm implements are now under way.

Construction Sites. Rainulators are also being used to study sediment yields from construction sites, where large areas of subsoils are often exposed to erosion. These studies are in Indiana, Nebraska, and Georgia. They are showing that much of the research and experience from farmland can be very usefully adapted to construction areas, and that the erosion equation and soil-erodibility nomograph can be quite helpful also under these nonagricultural conditions. Various surface conditions on construction sites, including the use of mulches other than plant residues, are now being evaluated in Indiana under simulated rain on scalped subsoils.

Topographic Modification. Bench-type and grass-backslope terraces with tile drains, and the scalped-soil problems associated with them, are under study in Iowa and South Dakota.

Graded furrows for water conservation and erosion control are under investigation at Temple, Texas, and have been studied in Georgia.

Factors associated with the development and growth of gullies are being investigated on the Treynor watersheds in western Iowa.

Factors affecting "sediment delivery ratios" for watersheds are being investigated at Treynor and in Missouri, Mississippi, Texas, Ohio, and probably a few other states.

Fundamental Research of Erosion Mechanics. For the best long-run assistance to the overall application programs, research must also provide a fuller understanding of the erosion and sedimentation processes and develop new basic concepts that can lead to real breakthroughs in future erosion and pollution-control technology. In the Corn Belt, the entire erosion-research team is actively participating in a concentrated effort to develop a mathematical erosion and sedimentation model that will be predicated on basic concepts and principles. If attained, the model will enable researchers to use mathematical simulation and high-speed computers to obtain the data needed for more thorough study of the interactions among soil, weather, topographic, and management variables. It will be a source of information for improved and more flexible control systems.

A framework for such a model has been developed *(4)*. It considers detachment and transport of soil material by rainfall and runoff as four separate but interrelated subprocesses. The masses of soil and water are routed along successive increments of slope. The sediment load carried from each increment to the next is the lesser of two values: (1) incoming sediment load plus detachment on that increment, or (2) the transportation capacity of the runoff from that increment. Thus the model describes soil movement all along a slope.

There are still many informational loopholes to be filled before the model becomes dynamic and dependable for widespread use. Physical concepts and principles affecting the four subprocesses are being investigated.

At Lafayette, an adjustable soil bed in an indoor laboratory, under simulated rainfall, is used to study effects of different levels and combinations of various factors under highly controlled conditions. Time-lapse movies are used to help study the erosion process. In another laboratory installation, turbulence and other flow characteristics of surface runoff are under study. Hot film probes and sensors measure both vertical and horizontal movement. The relation between micro-relief profiles and overland-flow characteristics is also under investigation.

SWC soil scientists at Purdue and Iowa State are investigating the reaction of different soil properties to the erosive agents and possible modifications of the soil to provide more favorable reaction.

At Morris, Minnesota, fluorescent particles are applied on rainulator plots to study the movement of various particle sizes within the plot during rainfall and runoff.

Some Urgent Research Needs

1. The basic relationships needed for completion of the mathematical erosion model.

2. Slope-length and drainage-area limits for effectiveness of agronomic practices such as the various no-plow methods for row crops. These must be in relation to slope steepness and shape, row direction, soil type, and amount and distribution of residues on the surface. Virtually all existing data for minimum-tillage practices have been obtained on relatively short slopes. Just how much concentration of runoff is required to break down the effectiveness of practices that depend on partial covers of residue or on surface roughness? This knowledge is absolutely essential to prudent and safe terrace-spacing design and to successful modeling of the erosion process.

3. Quantitative evaluation of the erosive potential of runoff that is not the immediate result of rainfall, such as runoff from thaw, drainage from a grassed area, furrow irrigation, etc. This erosive force is not measured by the EI rainfall factor but is highly important in some areas. The spring runoff in the Palouse Region is an example. The situation in the Gulf Coastal Plains is different but closely related; there, prolonged very high intensity rains quickly build up a protective sheet of water over large flat soil surfaces that negates the effect of the rainfall energy.

4. Extension of the slope-effect formula to slopes steeper than about 20 percent and longer than about 500 feet, and relation of slope-effect to soil, cropping, and management variables.

5. More precise evaluation of effect of shape of slope on soil detachment and transport.

6. New concepts and technology specifically directed toward erosion-control practices on construction sites.

7. Definition of conditions that determine the extent to which macro rills will form in the erosion process.

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Wood and Food Processing Wastes

Our task group is doing research on converting residues from two industries that are very important to Illinois in particular and the United States in general: wood and food processing. The residue problems under attack are of diverse origin, and innovative solutions are being sought for each problem. However, we all have a central theme, really a central goal: *the conversion of residues from liabilities to assets.* Thus we are not interested in how to dispose of a given waste more rapidly or economically—that is the province of our highly competent College of Engineering. Rather, we want to convert these residues or so-called waste materials into useful materials. Waste materials really have a negative value; we spend money to render them innocuous to the environment. Let us, rather, spend this money to transform this residue into a material needed by society, thereby recycling or expanding the utilization of our plant resources. As our population expands and our agricultural land supply shrinks, such transformation assumes increasing importance.

The many projects under way fall into three main areas: (1) utilizing wood residues for ornamental horticulture; (2) making wood substitutes from wood residues; and (3) converting food processing residues into feed and feed products. An interdisciplinary approach is being taken. Although the researcher closest to a problem is heading up a given project, he is being helped by others, usually from within the College of Agriculture but sometimes from other colleges and industry as well.

Utilization of Wood Residues for Ornamental Horticulture

Removal of bark from the log is the first step used by the sawmill in the process of producing lumber. Traditionally bark has been disposed of by dumping on the land or in a stream or by burning. Both procedures may pollute the environment and, more important, result in loss of a natural resource. The objective here is to further process these residues from a waste material into a useful by-product. Economics are very important; the selling price should at least equal the added processing costs minus the disposal costs.

Wood residues are already being used by the ornamental horticulture industry but much more research is needed. The work under way falls into three basic segments: the technical properties of bark, the use of bark as a growing medium for plants, and the use of bark as a mulch for highway slopes and shrub beds.

The pH of a growing medium can profoundly affect performance of the plant. Our research has shown that pH of the bark increased as the bark aged and that this pH increase varied with species of bark. We concluded that lime should not always be added to bark and that it is

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Report of the task group on plant residue and food processing wastes: M. P. Steinberg, leader, Poo Chow, J. B. Gartner, J. H. Hetrick, D. E. Johnson, J. T. Pfeffer, and G. C. Shove.

important to know what species of bark is being used. Furthermore, bark was found to contain a growth inhibitor. Different species had different amounts of inhibitor, ash showing the greatest growth inhibition and sycamore the least. Fortunately, this inhibitor can be inactivated by stockpiling the bark and composting for one month.

The source of nitrogen was also shown to be of technical importance to the growth of plants in bark; ammonium nitrate gave the best growth and urea the poorest growth at the same level of nitrogen. Particle size is also important. Very fine particles as well as large particles gave poor results while the best results were obtained with a mixture of intermediate particle sizes.

Conversion of Wood and Bark Residues to Panel-Board Products

Illinois ranks fourth nationally in the manufacture of wood products and total consumption of wood in all forms. The residue resulting from lumbering and milling represents three-fifths of all the fiber in the trees. Bark comprises 15 percent of the tree volume. Therefore, large amounts of wood and bark residues developed from lumbering and milling are available in Illinois.

The utilization of wood and bark residues is not well developed in Illinois, which imports all of the wood-base panel products from western or southeastern states. Two reasons for this are: (1) the residues produced here are from a variety of hardwood species while most panel-board products are made from residues of softwood species; and (2) the method for manufacturing wood-residue panel products from the hardwood residues is unknown. Liquid waste from paper mills presents a particularly serious disposal problem. The primary objectives of this study are to determine technical feasibility of converting low-value wood and bark residues to high-value panel-board products and to use pulping waste liquor from a paper mill instead of expensive synthetic adhesives as a binder in making board from wood residues. Preliminary information on the processing procedures necessary has been obtained, and measurements have been made of the properties of the board processed from the solid wood and bark residues combined with liquid waste from a papermill.

The residues were collected, for the most part, from Illinois wood-using industries as follows: red oak sawdust from a circular headsaw; white oak chips from a cooperage-stave mill; bark from white oak, cottonwood, and walnut species; and hard maple shavings from a furniture plant. Each residue was defiberized by treating with steam at pressures of 30 to 100 p.s.i.g. prior to mechanical grinding and drying to 8 percent moisture.

Eight percent of urea-formaldehyde, an interior-type adhesive, or 5 percent of phenol-formaldehyde, an exterior-type adhesive, mixed with 1 percent of wax emulsion was applied by an air-spray gun to the tumbling fibers of each residue type in a drum-mixer. After blending, the material was formed into a mat which was transferred to a hydraulic press with a platen temperature of 315° to 360° F. Steel stops were used to control the thickness of the finished board. Press time for the 5/8-inch-thick board was 9 minutes, and the density was 45 pounds per cubic foot. All processes followed commercial practice as closely as possible.

In addition, 400 gallons of sulfite waste liquor were also collected from a paper mill. In general, from the production of one ton of sulfite paper pulp, 10,000 gallons of waste liquor are produced. The waste liquor consists of 10 to 15 percent solid lignin. Since lignin is a natural bonding agent for the basic cell elements of all plants, it is possible to use pulping liquor as a binder in making the fiberboard from wood residues. Maple shavings from a furniture plant were soaked with enough sulfite waste liquor that 15 percent of the solid lignin was applied. The saturated maple shavings were dried and pressed into experimental boards. No synthetic adhesive was used, so both binder and raw material for this type of particleboard were wood residues.

The surface of all experimental boards was very attractive with various natural colors and texture of the different types of fibers. These boards can be overlaid by veneers or plastic overlays. All experimental boards were cut into specimens to test the bending strength, internal bond, screw-holding ability, and water-soaking properties. Preliminary results indicate that it is technically feasible to produce panel board from wood and bark residues from hardwood species in Illinois or in the Midwest. There is also a strong possibility of using sulfite waste liquor for an adhesive in particleboard. It is expected that kitchen cabinets, bedroom furniture, shelving, house paneling, floor tile, suitcases, decorative pieces, printing blocks, and colored panels can be made from these materials.

Food Processing Wastes

Cheese whey is the clear liquid residue that separates from the curd in making cottage cheese and other types of cheeses. About 22 billion pounds is produced in the United States each year. About half of this represents a terrible pollution problem; it has a BOD of 3,500 p.p.m., and although the dry matter contains much milk sugar, lots of B vitamins, and a small amount of high-quality protein, it has an obnoxious flavor. Because whey is mostly water and, consequently, expensive to dry, the dairy industry spends millions of dollars getting rid of it.

Another problem involves soybeans, which are used mainly for animal feed. Some of the crop goes to oil-extraction plants where the oil is made into margarine; the residue, called meal, goes to animal feed. This meal is one-half protein of a high quality so it would be highly nutritious, but people will not eat it because of a very bad flavor, which is characterized as beany or painty. To be specific, it smells like linseed oil. Food scientists have tried to remove as much as possible of this flavor and mask the residual flavor with spices; the resulting product is called "texturized vegetable protein." Other scientists have developed synthetic ham, synthetic turkey, and so on by extracting the protein from the meal and spinning it into fibers. This process, however, results in a pollution-causing residue and some of the bad flavor is still present.

Food scientists generally assumed that this beany flavor grows in the bean, put there by Mother Nature. Researchers in the Department of Food Science recently discovered that this is not true: the beany flavor is caused by an enzyme that becomes active as soon as the bean is broken. Fortunately, this enzyme can be destroyed by cooking the whole bean in boiling water. This simple process prevents the bad flavor from ever forming. Then the bean can be mashed or processed in any way with no flavor problem. The resulting bean has a pleasant, bland, nutlike flavor that is readily masked. We have used this treated whole soybean to develop a simulated milk.

Now by mixing this soy milk with cottage cheese whey, we have developed a soy-whey milk that is tasty and nutritious. This is truly converting a liability into an asset and conserving an important nutritional resource.

The first Allerton Conference on the environment one year ago recommended that research be done on refuse from sweet corn canning. This is under way. Our approach has been to apply a small amount of pressure on the cobs and husks, thereby squeezing out about half the weight as liquid. We want to economically stabilize the solid matter so it can be shipped as cattle feed. In addition, we are researching tomato pulp refuse from a tomato juice canning operation. Here the approach is to treat the material by neutralizing the natural acidity with ammonia. We hope the product will then be worth drying for cattle feed.

Nitrates and Animal Health

The problem of "nitrate poisoning" is not new to the agricultural community. Nonspecific intoxicative diseases which, in retrospect, can probably be attributed to nitrate toxicity were described over 100 years ago. The first detailed account of intoxication which followed ingestion of nitrates appeared in the literature in 1895 *(7)**: Since that time cycles of concern over nitrate toxicity can be identified by proliferation of reports on the subject in the literature. These include: the period from 1920 to 1930 when "oat hay poisoning" caused extensive livestock losses in the High Plains region of the United States; around 1940 when the role of nitrates in "corn stalk" and "oat hay poisoning" was clarified *(1)*; in 1945, when methemoglobinemia in infants was related to high nitrate content in artificial milk formulae *(3)*; and in the last decade as increased information in scientific and popular literature coupled with concern over the environment stimulated an awareness of the problem in the general populace. The theme of this session and a recent announcement by the National Academy of Science that a report on nitrates in the environment will be released by that agency in spring of 1972 are adequate evidence that concern over possible hazardous effects from nitrates has not diminished.

Mechanism of Action of Nitrate/Nitrite in Animals

The term "nitrate toxicity" used so frequently in the literature is actually a misnomer. It is known that most species have a relatively high tolerance to nitrates. Large doses may be given intravenously and the result is generally little more than increased water consumption and urine excretion, with a large part of the dose being recovered in the urine. It is generally accepted that reduction of nitrate to nitrite is required before toxicity will develop.

Nitrates taken orally are normally reduced in step fashion to NH_3 by the action of microflora of the gastrointestinal tract according to the following scheme:

Metal requirement		**Mo**		**CuFeMg**		**CuMgFe**		**MnMg**	
Oxidation-reduction	NO_3^-	$\xrightarrow{2e}$	NO_2^-	$\xrightarrow{2e}$	N_2O_2	$\xrightarrow{2e}$	NH_2OH	$\xrightarrow{2e}$	NH_3
State of N	+5		+3		+1		-1		-3

The optimal pH for nitrate reduction is 6.5, for nitrite reduction 5.6, and for hydroxylamine reduction 6 to 7.

In ruminants, reduction of nitrate occurs in the rumen. In monogastric animals, nitrate reduction occurs in the caecum or colon. Most nitrate ingested by monogastric animals is absorbed unchanged from the upper gastrointestinal tract and is subsequently excreted by the kidneys. An exception to this general rule occurs in the human infant, where an incompletely developed capability to secrete hydrochloric acid allows the gastric pH to become high enough to permit nitrate-reducing bacteria to reside high in the gastrointestinal tract and to reduce nitrates before they can be absorbed into the bloodstream. This is one factor which may account for the vulnerability of infants to methemoglobinemia.

Abnormally high concentrations of nitrite may occur in the blood under a variety of conditions:

—following accidental ingestion of high levels of nitrite in pure form or in normal feeding situations where a component of the ration has an abnormally high nitrite content;

—after a radical change in diet which may alter gastrointestinal pH in a direction favorable to nitrite production;

—accumulation of nitrite in the gastrointestinal tract as a result of nitrite reductase deficiency or deficiency of trace elements required in the nitrate reduction process.

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*Numbers in parentheses refer to references at end of paper.

Remarks by K.W. Sloan, Associate Dean, College of Veterinary Medicine, University of Illinois at Urbana-Champaign.

Nitrates and nitrites are readily absorbed from the gastrointestinal tract and may reach peak values as soon as two hours after oral dosing. Once in the bloodstream, nitrite may react with hemoglobin in a variety of ways, with the primary process being oxidation of the ferrous iron of hemoglobin to the ferric iron of methemoglobin. Methemoglobin is incapable of transporting or releasing oxygen to the tissues. Small amounts of methemoglobin are normally reconverted to hemoglobin by methemoglobin reductase (diaphorase). If the capacity for reconversion is exceeded, abnormal concentrations of methemoglobin will occur. Signs of toxicity may develop when 20 percent of available hemoglobin has been converted to methemoglobin; death usually occurs when methemoglobin levels reach 70 to 80 percent.

Acute Nitrite Toxicosis

Since methemoglobin is incapable of supplying oxygen to tissues, signs of nitrite toxicosis in all animals are primarily those of acute hypoxia. Typical signs of methemoglobinemia include: brownish discoloration of nonpigmented areas of skin and mucous membranes, staggering gait, rapid pulse, frequent urination, diarrhea, and labored respiration. Within one to three hours after onset of signs of intoxication, animals usually collapse, develop convulsions, fall into coma, and die. Vomiting may occur in monogastrics, since high concentrations of nitrite apparently produce severe irritation of the gastric mucosa. Pregnant cows that survive near-fatal methemoglobinemia may abort a few days after the acute episode. Typically a chocolate brown discoloration of blood and tissues is found at necropsy, along with hemorrhages of the heart and hemorrhage and congestion of lungs.

While diagnosis of acute nitrite toxicosis is more straightforward than is possible in subacute or chronic episodes, there are several intoxicants which may confuse a differential diagnosis. These include: sodium chlorate, cyanide, carbon dioxide, and carbon monoxide. Thus, diagnosis of acute nitrite toxicosis must be based on a history of ingestion of excessive levels of nitrate or nitrite, typical signs, nitrate or nitrite determinations of suspected feed or water, and—of foremost importance—nitrite and methemoglobin determinations on fresh blood from live or recently dead animals or on properly processed and stored blood samples.

Treatment of choice for methemoglobinemia is intravenous administration of a 1-4 percent solution of methylene blue. Methylene blue is thought to act as an electron acceptor for methemoglobin reductase enzymes and thus facilitates reconversion of methemoglobin to hemoglobin.

Chronic or Sublethal Nitrite Toxicosis

Various conditions in livestock have been attributed to long-term ingestion of sublethal levels of nitrate. These include: interference with thyroid function, disturbance of vitamin A nutrition, decreased fertility, abortions, lowered birth weights, decreased production of eggs and milk, and poor performance in the feedlot.

It is possible to find reference materials which indicate that all of these conditions are products of sublethal nitrite toxicity. It should be noted, however, that most evidence supporting this view is based on clinical observations or on extrapolation of data obtained from laboratory animals quite different from cattle, sheep, or swine in morphologic and physiologic constitution. In addition, efforts to reproduce chronic effects attributed to long-term ingestion of low levels of nitrate through well-controlled experimental dosing have generally been unsuccessful.

There still appears to be some uncertainty regarding the interrelationships between nitrate or its reduction products and vitamin A metabolism and storage. However, the *in vivo* levels of nitrite required for carotene or vitamin A destruction are such that nitrite toxicity itself would be the problem of more pressing concern *(4)*. Even so, it seems that the most important concern over vitamin A is the direct destruction of carotene by nitrate in rations prior to their consumption by livestock *(6)*.

Although abortions may occur in pregnant animals which survive acute nitrite intoxication, several well-controlled feeding studies have shown that prolonged ingestion of sublethal amounts of nitrate cannot be implicated as a cause of abortion *(5,9,10)*. In one study pregnant heifers were fed a balanced ration to which sufficient sodium nitrate was added to maintain methemoglobin levels at 20 to 30 percent or 40 to 50 percent. A causal relationship could not be shown between methemoglobinemia and abortions, nor were significant lesions observed which could be attributed to the treatment. Similar studies which support these results have been reported for sheep and swine.

Nitrates in the ration or in water have been blamed for less than acceptable production performance. Numerous studies have failed to demonstrate deleterious effects from long-term, low-level feeding of nitrate on weight gains, feed conversion, or production in cattle, sheep, swine, and poultry. Retrospective study of early reports seems to indicate that production decreases could more appropriately be related to low feed consumption due to unpalatability of the ration rather than to a direct effect of nitrates on livestock health. Indeed, it has been shown in several species that low levels of nitrate-nitrite ingested for a prolonged period appear to stimulate a compensatory erythropoietic response to elevated levels of methemoglobin which enables animals to adjust to relatively high levels of nitrate in feed or water.

Application of nitrogen fertilizers to farmlands is commonly incriminated as a factor in nitrate accumulation in plants and water and, by association, for acute and chronic nitrate toxicity in livestock. A positive correlation between excess nitrogen fertilization and poor animal performance has not been found in several studies in which the sole source of food was from plants grown on heavily fertilized soils *(2,5,8)*. In one of these studies two to three times the normal level of nitrogen was applied to pasturages without producing increased methemoglobin levels in animals which grazed them. While studies of this kind should not minimize the role which nitrogen fertilizers may play as pollutants of the environment, they do serve to emphasize that sweeping generalities regarding application of nitrogen fertilizers should be avoided.

Conclusions

The following conclusions relating to nitrates and animal health can be drawn from a recent review of available literature:

1. Signs of acute nitrite toxicity occur when nitrite is absorbed into the bloodstream and 70 to 80 percent of available hemoglobin is converted to methemoglobin. Most recorded outbreaks of acute nitrite toxicity have occurred under unusual circumstances involving accidental ingestion of nitrites by livestock or consumption of a ration component in which there has been an excessive accumulation of nitrate-nitrite.
2. Some aspects of the interrelationships between nitrate-nitrite and animal health require clarification. However, experiments designed to reproduce many of the chronic conditions attributed to long-term ingestion of nitrate-nitrite have generally been unsuccessful.
3. Clinical diagnosis of nitrite toxicosis should be supported by a history of consumption of excessive levels of nitrate-nitrite, nitrate or nitrite determinations on suspect feed or water, and nitrite and methemoglobin determinations on blood from live or recently dead animals.

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The Effect of Nitrate on Human Health

I would like to describe briefly the known detrimental effects to human health that may result from exposure to the nitrate ion. The harmful effects are largely confined to infants less than five months old, and the illness that results is called infantile methemoglobinemia (referred to as blue baby); this illness has been reported in many different areas within the United States and from a number of countries throughout the world during the last 25 years. There has recently been some speculation about other diseases resulting from exposure to nitrate; however, there is very little evidence at present to support this speculation.

The main sources of human exposure to nitrate are vegetables, cured meats, and water, and in each instance the nitrate concentration may vary greatly. With few exceptions, nitrate ion, by itself, is felt to be innocuous *(1)** and pharmacologically inert *(2)*. On the other hand, the nitrite ion is both pharmacologically active and potentially toxic and once absorbed into the blood stream, may convert hemoglobin to methemoglobin (Figure 1). Hemoglobin is the blood pigment that normally carries oxygen from the lungs to the tissues; however, the altered pigment (methemoglobin) can no longer transport oxygen and the physiologic effect of this is oxygen deprivation or suffocation. Under certain circumstances, to be explained later,

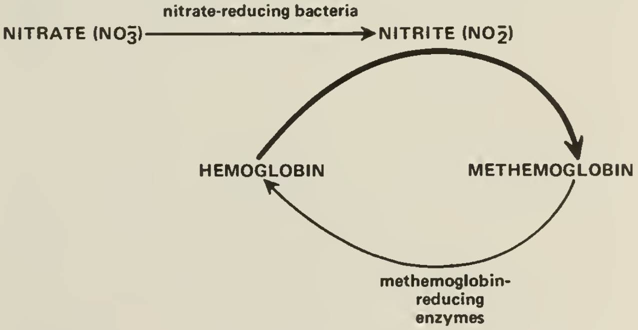

Figure 1. Basic reactions in the development of methemoglobinemia from nitrate in water.

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*All such numbers refer to references at end of paper.

Report by David H. Gunderson, M.D., Chief, Disease Studies, Water Supply Programs Division, Office of Water Programs, Environmental Protection Agency.

ingested nitrate may be converted to nitrite by intestinal bacteria; any nitrate not reduced to nitrite is rapidly absorbed and excreted in the urine. I would like to repeat then that it is the nitrite ion and not nitrate itself that is responsible for infantile methemoglobinemia.

The vast majority of nitrate-related health problems have resulted from exposure to nitrate in the drinking water. A number of cases have been reported of NO_2^- poisoning resulting from consumption of food containing excessive amounts of the NO_2^- ion, but by far the largest number of cases of infantile methemoglobinemia have been associated with nitrate in the drinking water. Comly *(3)* first associated nitrate in the drinking water with methemoglobinemia in infants in 1945. Since then many cases have been reported from numerous countries throughout the world. A review of the world literature in 1962 *(4)* revealed 1,060 cases in Europe, North America, and Africa since 1945. By now, it is estimated that the world total has risen to approximately 2,000 reported cases with a 7 to 8 percent mortality rate *(5)*. Because the disease is not required to be reported, we have no idea of its true incidence, but one investigator estimates that the reported cases represent only 10 percent of the actual number.

Almost all reported cases of methemoglobinemia have been in infants less than three months of age who have consumed high-nitrate water, usually greater than 100 mg./l. (milligrams per liter) as nitrate. However, cases have been reported at nitrate concentrations as low as 40 mg./l. (largely unexplainable).

Private wells have been associated with almost all reported cases of infantile methemoglobinemia, and although there is no nationwide surveillance of such wells, recent surveys indicate that high-nitrate private wells are common in some sections of the United States *(6)*. In a recent survey in Washington County, Illinois *(7)*, 72 percent of the rural wells sampled were above the U.S. Public Health Service standard of 45 mg./l. as nitrate, 50 percent above 100 mg./l.

A number of variables are important in explaining why some infants exposed to high-nitrate water develop methemoglobinemia while others exposed to the same high-nitrate water do not develop a clinical illness *(8)*, including the dose ingested, the bacterial reduction of nitrate to nitrite, and the biochemical equilibrium between hemoglobin and methemoglobin. The most obvious variable is the total dose of nitrate consumed by the infant during a given period, and the total dose will depend on the level of nitrate in the drinking water, the amount of water used in mixture with milk or base formula, the method of preparation of formula with water (for instance, if the water is boiled before addition to formula, the nitrate concentration may increase substantially), and finally the amount of water given without formula, either with juice or with sugar. A last consideration, and one that may be important in certain instances, is the possibility that the infant may be getting nitrate and nitrite from food in addition to that from the water.

Another important variable in the development of infantile methemoglobinemia is the extent of conversion of nitrate to nitrite in the upper gastrointestinal tract. Nitrate is not capable of producing methemoglobinemia, and normally when ingested will be absorbed and excreted in the urine unchanged. The adult normally has a highly acidic gastric juice, and this condition does not permit the growth of nitrate-reducing bacteria. However, the infant may have an incompletely developed capacity to secrete gastric acid, and this will allow the gastric pH to become high enough (5 to 7) to permit nitrate-reducing bacteria to reside in the upper gastrointestinal tract. From this position, the bacteria are able to reduce nitrate before it is absorbed into the circulation.

Finally, there are a number of factors affecting the equilibrium of hemoglobin and methemoglobin in the red blood cell. In the red blood cell, hemoglobin and methemoglobin are normally in a dynamic equilibrium, balanced between a natural tendency for hemoglobin to change to methemoglobin, and enzyme-catalyzed reactions that convert methemoglobin back to hemoglobin. As a result of this equilibrium, we usually find a methemoglobin of less than 1.5 percent of the total hemoglobin. However, in the young infant, there is a decreased activity of this enzyme system, and it may be more marked in some infants than in others; some infants are therefore obviously more susceptible to methemoglobinemia than others if exposed to a substantial amount of nitrite ion.

Control over any one of these variables would reduce the incidence of methemoglobinemia or even prevent the disease, but from a practical standpoint, preventive measures are centered on factors that determine the dose of nitrate. Because the level of nitrate in the drinking water is the one variable we can easily measure and the variable we have some control of, the level of nitrate in drinking water is of prime importance in preventing the disease. The recommended limit for NO_3^- in the drinking water is an attempt to prevent infantile methemoglobinemia by controlling only the first variable, and this limit should protect an infant regardless of how many other variables occur favoring methemoglobinemia.

There is also some recent evidence from several Russian publications *(9, 10, 11, 12)* that methemoglobin elevation may not be confined to the young infant, and these studies have related above-normal methemoglobin levels in older children to high nitrate levels in their drinking water. To obtain more information about the effect on young children of consuming high-nitrate water we conducted a study last summer in Washington County, Illinois *(13)*. A total of 102 children were selected and seen; 64 of these were consuming high-nitrate water (100 to 500 mg./l. as nitrate). In brief, our preliminary results indicate that the children in both high- and low-nitrate groups were in good general health. There was no large difference in methemoglobin between high- and low-nitrate groups. In children 1 to 4 years old who were drinking high-nitrate water, slightly higher levels were found in those having a higher total dose of nitrate. The difference was not great, and to be certain of this effect, a much larger number of children must be studied.

We confirmed the presence of marked bacterial contamination of water from the dug shallow wells with significant contamination in both the high- and low-nitrate wells. Of the 46 samples collected, only 5 were of acceptable bacteriological quality according to the WHO standard for individual water supplies (up to 24 coliforms per 100 ml.), only three were acceptable according to the U.S. Public Health Service drinking water standards. Fifty-four percent of the samples obtained had greater than 1,000 coliforms per 100 ml. with significant bacterial contamination in both high- and low-nitrate wells. It may be that the greatest hazard to human health from use of these dug, shallow wells in Washington County is from this marked bacterial contamination and to a lesser extent from the elevated nitrate level. This statement would appear to be true, at least, for young children and adults, but the use of this high-nitrate water for young infants could obviously be quite dangerous.

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Economic Impact of Regulations To Limit Use of Nitrogen Fertilizer

Previous speakers have discussed the nitrogen-related risks that occur in terms of animal and human health. Also on the risk or damage side of the role of nitrogen as an environmental factor are the effects (beneficial or harmful) of various levels of nitrate concentration on maintenance of desirable biota in lakes and streams. The problem facing decision-makers consists of weighing the risks of all of these possible damages against the benefits derived from the use of nitrogen in its many forms.

The analysis which follows is an example of the kind of information needed on a much larger scale to make rational policy judgments. Such analyses form a critical input to those who seek to find a policy which balances damages and benefits. (For other examples of costs of reducing the level of use of agricultural chemicals, see references *1*, *2*, and *3* at end of paper.)

In this part of our nitrogen study we are attempting to answer the question: If the level of use of nitrogen fertilizer is reduced, what will be the consequences for land use, farm income, food costs, and government payments?

The immediate impetus for this particular analysis was the consideration by the Illinois Pollution Control Board of proposed regulations for the application of plant nutrients *(5)*.

If we are to judge the proper balance between the contribution of fertilizer to crop production and the risk of damage from application of fertilizer to human and animal health and to streams and lakes, knowledge of at least two physical relationships is critical.

Considering the case of nitrogen fertilizer used on corn, the first relationship which we need to know is the one between nitrogen and corn yield (upper curve and left axis in Fig. 1). A second basic type of relationship deals with the effects of changing the level of fertilizer on the nitrate which appears in streams or lakes as a result of

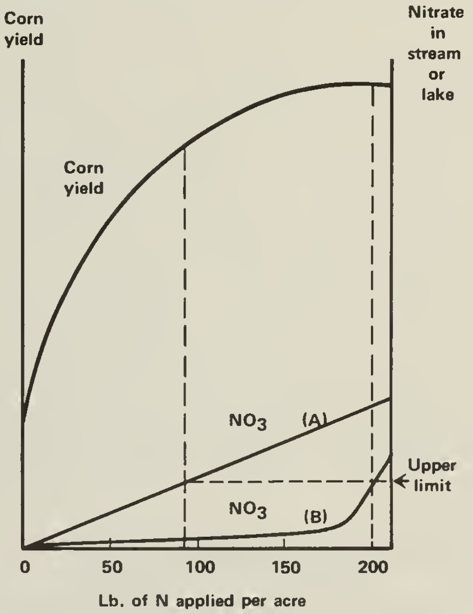

Figure 1.

Report by E. R. Swanson, Professor of Farm Management and Production Economics, University of Illinois at Urbana-Champaign.

nitrogen fertilizer application (curves A and B and right axis in Fig. 1). While a considerable amount of experimentation has been done to obtain estimates of the relationships of crop yield to amounts of fertilizer, substantially less is known about the impact of such fertilization on water quality. In fact, there appears to be little evidence to indicate whether relationship A or B or some other possibility best describes the empirical situation.

The critical nature of the relationship between fertilizer applied and the nitrate entering streams or lakes can be shown by comparing the consequences of assuming a relationship of the A type with the consequences of assuming a relationship of the B type (Fig. 1). If the level of nitrate concentration in lakes and streams is to be kept below an "upper limit," and if one assumes that the relationship is of the A type, a more severe restriction on fertilizer application will be required than if one assumes the relationship is of the B type. Similarly, the consequences for corn yield reduction are also different in the event of regulation (Fig. 1).

Because the nature of the relationship between the level of nitrogen fertilizer applied and the nitrate concentration in the relevant body of water is not precisely defined, to say nothing of the relationship between such levels of concentration and damage in its several forms, our economic analysis will deal only with those economic consequences which are generated by the fertilizer-corn yield relationship of the nature presented in Fig. 1. No attempt will be made to assess the value of the reduction of risk to human and animal health or the maintenance of a desirable biota in streams and lakes.

Method of Analysis

The general procedure to be followed is to specify certain food requirements for the United States (Table 1) and to note the effects (farm income, crop production patterns, and food costs) of restricting fertilizer use in Illinois at various levels. The basic solutions for the analysis were computed by the Center for Agricultural and Rural Development of Iowa State University by means of its environmental-policy model of U.S. agriculture *(4)*. The impact of the regulation of nitrogen fertilizer on Illinois corn is analyzed within a model which includes all of U.S. agriculture. The continental United States was divided into 150 agricultural production regions and 31 consuming regions. The Illinois production regions are shown in Fig. 2. Adjustments to meet the specified food needs at minimum cost can be made by shifting acreages of basic crops within certain limits, and by releasing land from federal set-aside programs. In recent years, the total amount of these acres in the United States has approximated 55 million. The results presented below deal only with 1980. Analyses for 1970 and 1975 are available in reference *5*.

Corn Yield Response to Nitrogen Fertilizer

The response to nitrogen fertilizer used in each of Illinois' six production regions is given in Table 2. This takes into account regional differences in yield and response to fertilizer. These response curves assume that the quantities of P and K also increase along with the N. These responses more closely approximate the experience of commercial farmers than do the results of experimental fertilizer trials. However, even these responses of yield to nitrogen are somewhat higher than those experienced on

Table 1. Projections Used for Nitrogen Analysis

Parameter	1980
Population	230,000,000
Income per capita	$3,250
Per capita consumption	
Beef, lb. carcass wt.	127.3
Pork, lb. carcass wt.	58.3
Broilers, lb. dressed wt.	47.0
Lamb, lb. carcass wt.	2.8
Eggs	290.0
Milk, lb.	566.0
Imports	
Beef, lb. carcass wt.	2,791,000,000
Pork, lb. carcass wt.	426,000,000
Broilers, lb. carcass wt.	-117,000,000
Exports	
Wheat, bu.	600,000,000
Feed grains, tons	18,500,000
Oilmeals, tons	23,300,000
Cotton, bales	2,000,000

Source: Estimates are based on data published by the U.S. Department of Agriculture and other official sources.

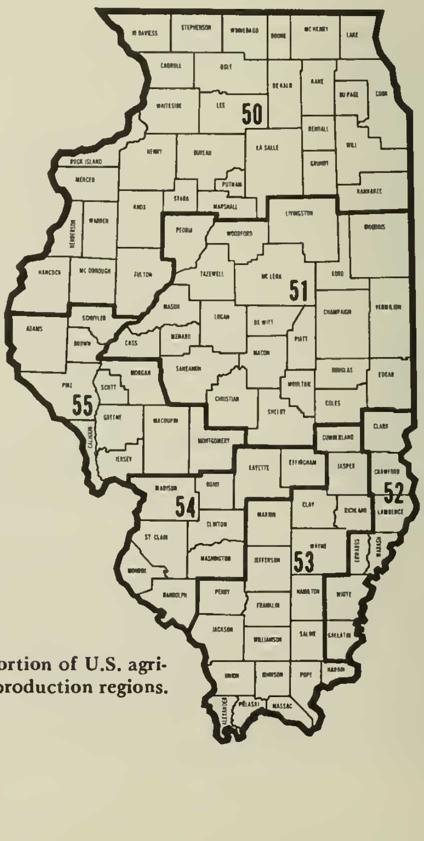

Figure 2. Illinois portion of U.S. agricultural production regions.

Table 2. Corn Yield Response to Applied N

Lb. of N per acre	Region 50	51	52	53	54	55
	(bushels per acre)					
0	60.0	59.0	38.0	30.0	32.0	55.0
50	91.6	86.9	67.5	53.8	53.8	73.3
100	110.0	105.9	82.2	70.3	71.9	88.4
150	117.8	115.0	88.3	78.6	82.3	99.4
200	120.0	118.3	90.0	80.0	84.4	105.0

Source: "Crop Yield Response to Fertilizer in the United States," Stat. Bull. No. 431, 1968.

the average in Illinois. Table 3 gives the Illinois corn yields during the period 1966-1970 in each of the six regions. An average of 107.5 pounds of N in the form of commercial fertilizer was applied per acre of corn during the five-year period. It can be seen (Fig. 3) that this is somewhat below the response curve used in evaluating the impact of fertilizer regulations. Figure 3 is a response curve based on a weighted average of the regional yield responses in Table 2. Since the yield response relationships are somewhat higher than those which apparently have been experienced on commercial farms in the last five years, they are assumed to approximate what is likely to be the corn yield response to nitrogen fertilizer in the near future.

Table 3. Illinois Corn Yields 1966-1970

Region	1966	1967	1968	1969	1970	Avg.
	(bushels per acre)					
50	86.9	98.4	93.7	100.2	76.9	91.2
51	83.9	106.3	91.0	111.2	85.2	95.5
52	62.0	93.9	75.9	78.5	50.1	72.1
53	56.5	84.9	70.2	63.7	42.2	63.5
54	55.9	90.3	72.9	73.8	53.1	69.2
55	73.7	101.2	90.8	88.1	67.6	84.3
					Weighted average =	88.06

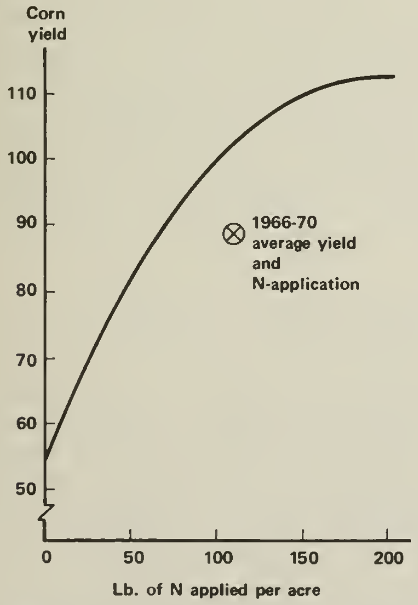

Figure 3. Pounds of N applied per acre of corn, weighted average of six regions.

In Table 4, I have indicated the returns above fertilizer costs for the various levels of fertilizer, assuming the response relationships shown in Table 2. Note that, in general, the highest return occurs at about 150 pounds. Regions 51 and 55 are exceptions, but the increase in returns is very small at levels above 150. This means that with the present technology, and probably into the reasonably short-run future, the economic incentives for higher levels are probably not very strong.

Table 4. Returns Above Fertilizer Cost[a]

Lb. of N per acre	Region 50	51	52	53	54	55
0	$ 60.00	$ 59.00	$38.00	$30.00	$32.00	$55.00
50	84.50	80.50	60.70	46.60	46.90	67.20
100	99.60	95.90	71.20	59.00	61.00	78.00
150	104.50	100.80	73.80	63.80	67.80	86.10
200	104.20	101.30	72.80	62.60	67.20	89.00

[a] Prices: Corn, $ 1.00 per bushel; N, $ .048 per pound; P, $ .1789 per pound; K, $ .0442 per pound. Fertilizer costs include added P and K accompanying increases in N.

Source: "Crop Yield Response to Fertilizer in the United States," USDA Stat. Bull. No. 431, 1968.

Levels of Nitrogen Considered for Economic Analysis

We have chosen to analyze the economic consequences of restricting application of nitrogen fertilizer to 110 pounds (approximately the average in the last five years) and then to 50 pounds. The results of these restrictions will be compared with those from "unlimited" use of nitrogen which will be assumed to follow approximately the increases in use which have occurred in recent years.

Effect of Illinois Nitrogen Fertilizer Restrictions on Land Use—Illinois and United States

As mentioned earlier, the analytical procedure requires that the food and export requirements (see Table 1) be produced at a minimum cost. This implies that shifts in acreages, not only in Illinois but also within regions and between regions in the United States, may occur in order to meet these objectives. In Table 5, we have presented the effect on land use for the five principal crops—wheat, corn, other feed grains, soybeans, and cotton using 1980 food and export requirements. The change in diverted acres (note the next to the bottom line for the United States) indicates that government policy reflects the need for increased acres by reducing these, for example, from 53 to 50 million acres. The acreage diverted by government programs has varied a good deal in the last five years: 1966—63 million, 1967—41 million, 1968—49 million, 1969—58 million, 1970—60 million.

Note that in Table 5, as we restrict nitrogen from 110 to 50 pounds, corn acres drop from approximately 8.8 million to 6.4 million. These acres are displaced primarily by increases in soybeans and wheat. For the analysis, upper and lower limits on diverted acres were based on the historical pattern of compliance by Illinois farmers. The 2.2 million reflects the lower limit of this historical base.

The impact of regulation in Illinois on land use in the entire United States can be seen at the bottom of Table 5.

Note the increases in corn and wheat acreage as restrictions are placed on nitrogen in Illinois. However, partly because of the increase in specialization of Illinois in soybeans, the total U.S. soybean acreage declines as we move from a 110-pound restriction to a 50-pound restriction. This means that when corn in Illinois is disadvantaged by a restriction on nitrogen, the comparative advantage of soybeans in Illinois is improved sufficiently to shift other areas out of soybeans. These other areas have lower yields, hence the total acres required for soybeans is less. Note also a marginal impact on cotton.

Table 5. Effect on Crop Acres of Illinois Limitation of N, 1980

	Unlimited N	110 lb. per acre	50 lb. per acre
		(million acres)	
Illinois			
Wheat	1.1	1.1	1.2
Corn	8.8	8.0	6.4
Other feed grains	.3	.3	.3
Soybeans	7.7	8.5	10.1
Diverted acres	2.2	2.2	2.2
Total	20.1	20.1	20.2
United States			
Wheat	39.6	39.8	39.8
Corn	51.6	52.9	55.2
Other feed grains	41.1	41.1	41.1
Soybeans	44.8	44.6	44.1
Cotton	13.1	13.1	13.1
Diverted acres	53.0	51.7	50.0
Total	243.2	243.2	243.3

The same general pattern was noted in the analyses for 1970 and 1975 *(5)*. The general effect of regulation is to weaken Illinois' competitive position with respect to corn-growing and to cause some shifts in the location of crop production in other areas of the United States due to the increases in soybean production in Illinois. The domestic food requirements and export requirements assumed in Table 1 for 1980 can be met with the acreages now available and still have approximately 50 million diverted acres in 1980. This is under the assumption of a 50-pound nitrogen fertilizer restriction on application on Illinois corn. The effects of a national restriction are discussed below.

Effect of Illinois Nitrogen Fertilizer Restrictions on Income—Illinois and United States

The effects of limiting nitrogen on corn in Illinois will also have an economic impact on the income of Illinois farmers, as well as all U.S. farmers. Much of this impact depends on the nature of government programs. In this analysis, we assume that the government programs will continue approximately as in the recent past, but that the need for added acres from "diverted acres" will be recognized. In Table 6, we indicate the effect on income of an Illinois limitation of nitrogen fertilizer on corn for the year 1980. Results for 1970 and 1975 are reported in reference *5*. They reflect the same general pattern as the 1980 results. The total revenue to Illinois farmers decreases as we increase the restriction on nitrogen while total revenue of U.S. farmers increases. Because of the nature of the aggregate domestic demand for agricultural products, a decrease in production will increase total revenue. The total amount of government payments for diverted acres decreases because there are fewer diverted acres. For example, the total U.S. government payments to farmers in 1980 would, under a 50-pound restriction on nitrogen fertilizer in Illinois, drop from 3.340 billion dollars to 3.147 billion dollars (Table 6).

Table 6. Effect on Income of an Illinois Limitation of N on Corn, 1980

	Unlimited N	110 lb. per acre	50 lb. per acre
Illinois			
Total revenues, mil.	$ 3,128	$ 3,051	$ 3,006
Net income per farm	$11,956	$10,911	$10,096
United States			
Total revenues, mil.	$59,127	$59,347	$60,244
Net income per farm	$ 7,928	$ 7,936	$ 8,410
Total government payments, mil.	$ 3,340	$ 3,254	$ 3,147

Effect of Illinois Nitrogen Fertilizer Restrictions on Food Costs—United States

We have now examined the impact on farmers' incomes, both in Illinois and in the United States, and also the change in taxpayers' contribution in the form of government payments. It is now of some interest to analyze the effect on U.S. food prices of the limitation of nitrogen on corn in Illinois. With the rather severe restriction of 50 pounds of nitrogen fertilizer per acre of corn, but only in Illinois, the increases in food prices range from 3 to 6 percent. This price increase is an item deserving consideration in weighing the costs of fertilizer use reduction against environmental damage.

Effect of a National Policy of Restricting Nitrogen Fertilizer Use

Mayer and Hargrove *(4)* have made estimates of the effect of national restrictions on nitrogen fertilizer use using the same basic model that was employed for the Illinois analysis presented above. Their results are not directly comparable to those presented above because the "unlimited" level of N is not considered. According to their analysis a nationwide elimination of nitrogen, as compared to a limit of 110 pounds, would cause the beef and pork prices at the consumer level to increase about 25 percent under conditions projected for 1980.

Concluding Remarks

Estimating the economic impact of restricting nitrogen fertilizer is just one example of examining the consequences of environmental-quality options that are before us. The preceding analysis is a first approximation of the kind of information needed. More comprehensive analyses are needed which would, for example, indicate the differential impact of regulation on farms operating at various levels of technology and also the differential impact of changes in food costs on various income groups. Finally, the estimates of environmental-quality gains from control of agricultural practices need to be more accurately quantified. It is not necessary to place dollar values on the benefits (reduction of damages), but it is necessary to know the physical magnitude of the benefits in such terms as improvement of human health and other environmental objectives.

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Social Response in Environmental Quality

A great amount of time has been spent at this conference examining many complex technological problems associated with environmental quality. It is apparent, however, that environmental quality is a social problem as well as a technological problem. As a contemporary social issue, environmental quality affects every person, every institution, and every segment of our society. It has brought to public attention the intricate relationships that exist between man and his physical environment. The decisions and actions of man (individually and collectively) have led to the environmental crisis; man is physiologically, psychologically, economically, and socially affected by pollution and the deterioration of the ecosystem; and man will devise corrective actions and regulatory mechanisms to improve his environment. The ultimate test is whether individuals and communities will accept recommended practices and regulation in order to improve the quality of the environment for society in general.

Two research projects initiated by sociologists in this task group are aimed at learning more about how people and their institutions are responding to the challenge of improving environmental quality. The first study deals with community mobilization for environmental quality purposes while the second examines responses to the issue of alleged water pollution from fertilizers. A brief description of these studies follows.

Communities and the Environmental Quality Issue: Some Research Priorities (A. J. Sofranko and W. M. Bridgeland)

If any single lesson has emerged out of recent experiences with environmental quality issues, it is that determination by both citizens and government is necessary to bring about a changed environment. Citizen awareness has reached the point where we now observe a closer scrutiny over public planning; new environmental quality groups have formed at the national, state, and local levels; in some localities adversary proceedings have been undertaken by citizen groups; and other individuals have altered their life styles in line with a newly emerging "environmentalist ethic." At both federal and state levels of government, general social concern for the state of the environment has resulted in a gradual assumption of responsibility for that environment; legislation has been enacted, regulatory agencies have been set up, and in some cases funds have been allocated to aid in modernizing facilities and eliminating sources of pollution. Still, response to the issue of environmental quality has been, at best, uneven. In many communities we notice scant interest among residents over the environment and local governments that are unwilling or unable to regulate polluters, enforce existing legislation, or comply with state and federal standards.

Report of task group on social assessment and rural development: H. J. Schweitzer, leader, F. C. Fliegel, A. J. Sofranko, and J. C. van Es.

Our current research focuses on several aspects of response to the environmental quality issue at the local community level. The central thrust of our inquiry is on "community mobilization" for environmental quality purposes. Along one dimension of this issue, we are examining local government resource mobilization, and along another, public involvement in the environmental issue.

Some of the questions we hope to find answers to in our research are:

1. What factors seem to explain why in some communities citizens are actively concerned about environmental quality and in others they are not, and why in some communities local government is committed to improving the environment and curbing polluters, and in others it shows little initiative for enforcing standards or complying with existing regulations? Is there something distinctive about the more active communities? Does the actual state of the environment have anything to do with the level of concern?

2. How is the issue of environmental quality viewed at the local level? How does environmental quality rank in terms of priority among other community issues? Given the present availability of funds, what sorts of environmental improvements could communities be making? What sort of relationship do community leaders see between attracting and keeping industry and strict enforcement of environmental standards? And in light of the fact that Illinois now has a state environmental protection act, what role do municipal leaders see for communities in the area of environmental quality? Do they view the state legislation as having preempted standard-setting and regulatory functions at the local level, thus removing environmental issues from the sphere of local concerns?

3. Is there any substance to the notion that communities develop a tradition of innovativeness or progressiveness over the years, that is, have the communities that responded more quickly to urban renewal, public housing, zoning, and fluoridation issues been more responsive on the environmental quality issue? If so, what are some of the factors that seem to explain the emergence of such traditions?

4. Given the findings we come up with, what strategies or sets of strategies can be devised to better inform community leaders and citizens of their potential roles in environmental improvement and, second, what sorts of communities ought we to focus future efforts on?

In our research, community is synonymous with municipality. The sample for the study includes all Illinois municipalities between 10,000 and 50,000 population. The focus on these 130 medium-sized Illinois communities is in contrast to much of the recent research that has been done on community adoption and innovativeness, which has used national samples and studied large cities. We are examining environmental quality in middle-sized municipalities because of the prevalence of this size of community in Illinois (and in the nation), and because of the importance of both citizens and local government to the environmental quality issues in communities of this size.

The Problem of Defining Community Response to Environmental Quality

Our initial problems in the research were defining governmental mobilization and public participation, or citizen mobilization. Despite the general feeling that some communities are more progressive, modern, and forward-looking than others, and that community systems are continually introducing new ideas, activities, processes, and services, finding ways of determining response to the environmental issue at the community level has proved to be most difficult. The more obvious kinds of indicators such as budget expenditures, ordinance enforcement and enactment, and community self-modification, while not irrelevant as indicators of response, do not suffice as single measures nor do they permit easy comparisons across municipalities. Some municipalities, because of an industrial economic base or of proximity to heavy industry or to large standard metropolitan areas, are more aware of environmental problems. Other communities, because of special-interest groups advocating change, have made considerably more progress than others.

The dual role of municipal government in environmental quality is well recognized. On the one hand, municipal governments are often among the most flagrant violators of air- and water-pollution standards, and municipal operations have contributed heavily to the existing levels of pollution. Still, on the other hand, they are one of the more effective forces for ensuring adherence to standards, for complementing coverage of state and federal directives, and even for passing legislation and adopting standards exceeding those set at higher levels of government. So far, however, municipal response in Illinois has been rather uneven. Some governments have placed great emphasis on environmental administration. This has been evidenced in attempts to purposively shape the community environment and to control citizens' actions in relation to that environment.

The present national movement for improvement of environmental quality may have provided an impetus to local government efforts, and much of what has been accomplished at the community level may have been out of obeisance to environmentalists. Still, these tendencies to respond primarily to external forces should not obscure past community initiative and efforts along lines of environmental administration. The basis for such optimism is the recognition that some Illinois municipalities meet the standards set forth in the Environmental Protection Act and have enacted and enforced measures consistent with provisions in it.

The political process has been broadly defined as "the exercise of power by certain individuals or groups over others" for the purpose of regulating behavior. In developing an index which we hope will gauge level of governmental response across the 130 communities in our study, we raise the fundamental question of how municipal governments have used their powers to control the behavior of individuals and groups in the community, including the behavior of the municipality, so as to bring them in line with standards of improved environmental quality. The complex of components referred to as "environmental quality" in our research parallels the dimensions of the issue given in the Illinois State Environmental Protection Act (H.B. 3788), namely: "air, water and other resource pollution, public water supply, solid waste disposal, noise . . ."

The level of local governmental mobilization index we are devising gauges the extent of municipal government control over use and abuse of air, land, and water within the municipality. The indicators we have decided to include in our "governmental mobilization index" include: (1) the presence or absence of ordinances designed to safeguard different aspects of the community's environment, (2) extent of enforcement of these ordinances, and (3) presence of an organizational arrangement within the local government for monitoring violations and receiving environment-oriented complaints.

We have attempted also to gauge what may be described as citizen mobilization or "activeness" over the issue of environmental quality. At the base of our effort is recognition that communities differ in extent of mobilization of human resources within the community, popular involvement in voluntary efforts to improve the community, concern for improvement in environmental quality, etc. Regarding the environmental issue, in some communities new ad hoc and informal groups have emerged to form local quasi-lobbies; clean-up and recycling campaigns and drives have been initiated; cultural activities with an environmentalist motif have been promoted; ordinance violations have been reported; and so forth. The importance of such citizen involvement in environmental quality issues is well stated by Caldwell: "The political strength of the environmental quality movement still depends very heavily upon the aroused determination of organized citizens. It is not yet firmly based anywhere within the structure of official government. Political systems do not accommodate all issues equally, and environmental quality appears to be one of those areas of public decision to which the institutional arrangements of American government are not especially favorable."

Citizen involvement in an issue-area such as environmental quality may take the form of joining or working through existing community organizations for change, living some personal environmentalist ethic, displaying concern, and participating ad hoc protests and newly formed special-purpose citizens groups. It is these latter modes of expression that we hope to measure. The citizen activities we will be using to measure the level of public mobilization are activities whose primary purpose has been to demonstrate and focus awareness of the environmental problem, to effect change at the local community level, or to do both.

The items making up our measure of citizen mobilization encompass several broad areas of public activeness: (1) emergence of local environmental quality groups; (2) increased pressure by citizens and citizen groups on municipal government to utilize environmental quality criteria in its policy making; (3) attempts to make local enforcement agencies more aware of environmental quality infractions and responsive to those infractions; (4) attempts at urging local media to expand coverage of environmentalist activities and to take a stronger, or pro, environmental quality stance; and (5) pressure on local businesses to bring about compliance with environmental quality standards.

Some Explanatory Factors for Community Mobilization

"Community structure" refers to the "internal social organization of communities." From past research on community response to issues such as public housing, urban renewal, suburb annexation, community conflict, adoption of nonpartisan form of government and fluoridation, and educational reform, we notice that community structure has been shown to be an important factor in explaining types of policies local government adopts, participation and extent of participation in new types of programs, and enactment and enforcement of new policy measures.

The community structure characteristics we have selected for examination against level of citizen mobilization are: (1) socioeconomic status of the community (distribution of income, education, and occupations); (2) extent of community integration; (3) degree of economic diversification; (4) community heterogeneity; (5) political participativeness; (6) age structure of the population; (7) presence/absence of institutions of higher learning; and (8) organizational density, or the widespread presence of voluntary organizations.

When looking at level of governmental mobilization, we will include form of government and several more economic variables, in addition to some of the structural features included above.

In all cases we will be careful to control for community size so as not to let our results be influenced by the number of people in a given community.

This is a brief outline of but one portion of the research we are currently conducting on environmental quality issues at the community level. The data we obtain here may help us to understand more fully the influence of community structure on community processes, make recommendations to individuals working in community development about the implications of community characteristics for their programs, and indicate the types of community characteristics for their programs, and indicate the types of communities where renewed efforts and new strategies of change will have to be developed if environmental quality regulations and new programs are to be adopted.

Decision-Making Regarding Nitrate Pollution of Public Water Systems: A Case Study of Decatur, Illinois (Carol Kronus and J. C. van Es)

The recent concern with improving the quality of the environment has witnessed a lengthy series of real and imaginary crisis situations. In many ways the occurrence of emergencies, both at the local level and at the national level, has played and will continue to play an important role in deciding the actions that will be taken to control environmental quality.

It is clear that the definition of what comprises crisis conditions is only partially and often erratically related to the existing physical conditions in the environment or to the state of knowledge. However, the conditions under which pollution issues become defined as "social problems" or as crises are largely unknown. The conditions under which objective environmental conditions are converted into social problems are as unclear as is the process through which such conversion takes place.

The *New Yorker* (September 25, 1971) contained a condensed version of a book by Professor Barry Commoner, *The Closing Circle.* The article states that the water supply of the city of Decatur displays very high levels of nitrate in the spring, during the periods when farmers apply nitrogen fertilizers in heavy concentrations. The article further argues that "More detailed studies . . . showed . . . that a minimum of sixty percent of the nitrate in Lake Decatur is derived from fertilizer used on the adjacent farms. There is now little doubt that the nitrate problem in Lake Decatur arises from the intensive use of artificial nitrogen fertilizer on the neighboring farms."

In the same article, research results were reported from studies undertaken by Dr. Gelperin, University of Illinois Medical Center, in a number of Illinois counties on the relationship between water nitrate levels and infant mortality. In the *New Yorker* article, Commoner quotes the following conclusion reached by Dr. Gelperin: "The evidence indicated that high levels of nitrate in the water, as found in these counties, may increase the infant mortality rate among female babies." Commoner continues by stating: "This may be the first evidence of the cost in human health of the intensive use of nitrogen fertilizer." Commoner's article gave wide publicity to a simmering controversy and in the process also produced one of the strongest statements of conflicting rural-urban interests.

The controversies surrounding the nitrogen found in Lake Decatur, the water supply of the city of Decatur, provide the opportunity to study some of the variables involved in the emergence of an issue, and its subsequent life history.

The research has as its specific objectives:

1. To determine the conditions under which pollution problems are publicly recognized;
2. To analyze the decision-making processes which lead to effective control of pollution sources, or alternatively, to the dismissal of the pollution issue.
3. To determine if the farmers will rely on existing farmers' organizations for action and supporting services, or if they will create ad hoc organizations to cope with this threat to their interests.
4. To identify the various interest groups which are mobilized in such a controversy, the role they play in the controversy, and the resources they have at their disposal.
5. To determine to what extent and in what way the general population is mobilized in support of various sides in pollution issues.

The research involves interviews with the key actors in the decision-making process concerning the nitrogen pollution of Lake Decatur. In addition, sample surveys are under way with residents of Decatur, farmers of Macon County, and leaders of voluntary organizations in Decatur and Macon County. The researchers are attending the public hearings on plant nutrient use held by the Environmental Protection Agency in order to gather additional information about this issue.

Fertilizer Nitrogen Use by Crops and Its Movement in Soil

Crops contain more nitrogen than any other essential nutrient. Large quantities of nitrogen are "hauled to the barn" in harvested crops. Illinois soils are incapable of supplying the nitrogen required for high yields of nonleguminous crops like corn. We add nitrogen fertilizer to increase yield by increasing the amount of nitrogen available for crop use.

Added Versus Removed Nitrogen

Much has been written and spoken about the amount of fertilizer nitrogen added to Illinois soils. Little has been said about nitrogen removed in harvested crops. We calculated the amount of nitrogen removed in harvested corn silage and in the grain of corn, wheat, oats, barley, and rye (Figure 1). (Soybeans and hay were not included since nitrogen fertilizer is rarely added to these crops. We are also aware that some nitrogen is added to non-agronomic plants that include vegetables, lawn grasses, orchards, golf courses, etc. But, the agronomic crops listed above probably account for more than 95 percent of the fertilizer nitrogen applied in Illinois.)

There has been a recent reversal in nitrogen added as fertilizer and total nitrogen removed in harvested crops.

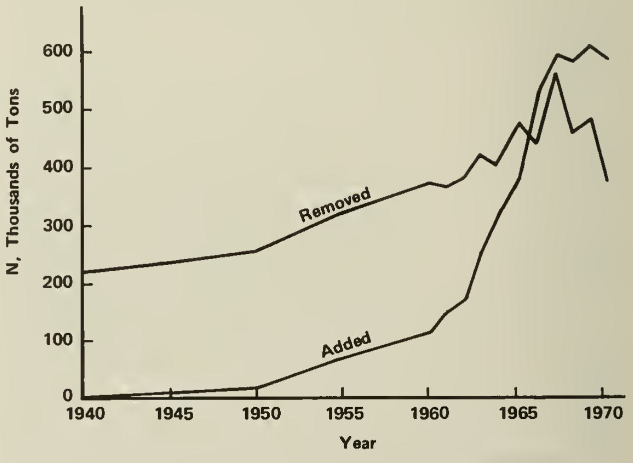

Figure 1. Nitrogen added to Illinois soils as fertilizer, and total nitrogen removed in harvested crops.

Report of the task group on plant nutrients as water pollutants: L. F. Welch, leader, F. A. Bazzaz, R. H. Hageman, R. H. Harmeson, B. A. Jones, F. J. Stevenson, and R. L. Switzer.

Farmers added only 1 percent as much fertilizer nitrogen in 1940 as was removed (Figure 1). The reversal occurred for the first time in 1966 when more fertilizer nitrogen was added than harvested. In 1970, 55 percent more nitrogen was added than removed.

Corn grain is the big remover of nitrogen in Illinois. Since added nitrogen has been fairly constant since about 1967, the variation in "added as a percent of removed nitrogen" is largely a reflection of corn produced. For example, state average corn yields were 100 bushels per acre in 1967 when added nitrogen was only 6 percent more than removed, but in 1970 an average yield of 74 bushels per acre (caused by southern leaf blight) resulted in 55 percent more nitrogen being added than removed.

These data by themselves do not indicate if Illinois farmers are overfertilizing or underfertilizing with respect to economic returns to the farmer. Field research has indicated that the economic optimum rate of nitrogen occurred when 37 percent more was added than removed. Utilizing the field data as a criterion, 1970 average corn yields were not limited by nitrogen.

The added and removed data in themselves do not reveal the contribution of fertilizer nitrogen to water quality. However, ecologists state a basic law that says "everything has to go somewhere." Using this law, the data do indicate that the potential effect of fertilizer nitrogen on water quality was greater in 1970 than in 1940.

Nitrogen Behavior in Soil

Once in the soil, nitrogen may be (1) absorbed by plants, (2) lost by leaching, (3) lost by erosion and surface water runoff, (4) lost as gases, and (5) retained in the soil. A host of biological, climatic, and soil factors influence what happens to the nitrogen. If nitrogen remains as the positively charged ammonium ion, it will not readily leach because it is held by the negatively charged clay particles. Nitrate is negatively charged and generally is not attracted by clay. Nitrate is called a mobile ion because it moves so freely with soil water.

The final form of nitrogen in soil is nitrate, whether the original source was fertilizer, leguminous plants, manure, or sewage. Once in the nitrate form, nitrogen from all sources behaves alike in that it potentially can affect water quality.

Recovery of Fertilizer N by Corn

Figure 2 shows data from the Research Center at DeKalb where 50-pound increments of nitrogen were added to corn. Yield followed the typical diminishing returns curve in that each successive increment of nitrogen increased yield less than the preceding one. This is to say that the lower rates of nitrogen were more efficient than the higher rates. The most profitable rate of nitrogen was 180 pounds per acre and this resulted in a yield of 143 bushels per acre.

With no nitrogen added 60.3 pounds of nitrogen were in the grain and this represents a "loss" in soil nitrogen. With 50 pounds of added nitrogen there were 41.0 more pounds of nitrogen in the grain than were added. But, at 180 pounds of added nitrogen the amount added to the soil was 52.2 pounds greater than the amount removed in the grain. Thus, at the most profitable rate and after corn harvest, there were 52.2 pounds more nitrogen than initially and this residual nitrogen may potentially contribute nitrate to streams. The rate of fertilizer nitrogen where N added equaled N removed was 117 pounds.

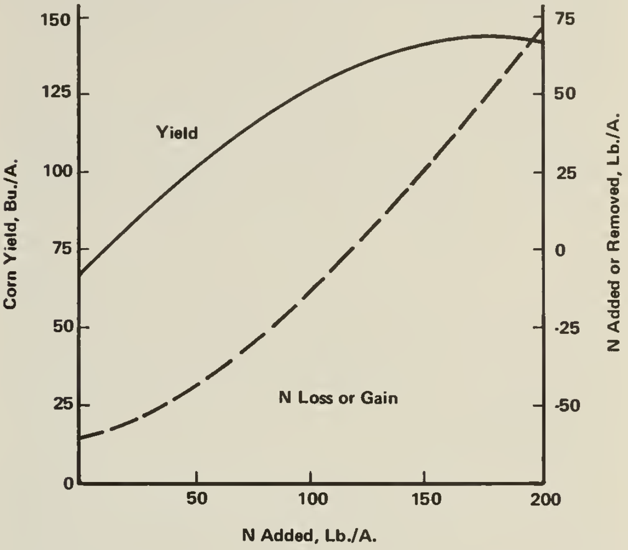

Figure 2. Corn yield with rates of fertilizer nitrogen, and gain or loss in soil nitrogen.

Time of Nitrogen Uptake by Corn

Only a small amount of nitrogen is taken up by corn from emergence to 30 days after emergence (Figure 3). Plant uptake of nitrogen is rapid for the next 80-day period, which corresponds to the "grand period" of growth. Thus, it is necessary that considerable nitrogen be in the soil for only about four months for corn culture. The challenge for researchers is to determine feasible means of keeping nitrogen levels in the soil low during the eight months when corn is not growing, yet maintaining adequate nitrogen during the period of corn absorption.

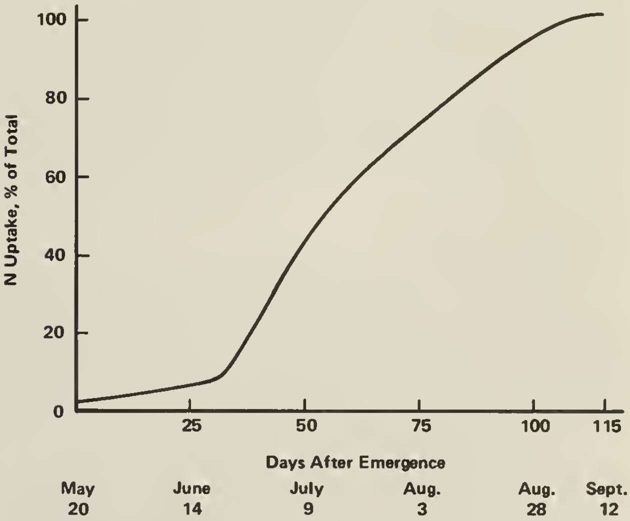

Figure 3. Nitrogen uptake by corn (adapted from Hanway). The calendar dates are for central Illinois.

It is relatively easy to supply plenty of nitrogen during the period of corn absorption by fertilizer addition. Maintaining low levels of nitrogen during the non-absorption period appears to be much more difficult. Lower levels of nitrogen after corn maturity may be achieved by (1) increasing the efficiency of fertilizer nitrogen uptake so that less remains in the soil after corn absorption ceases, or (2) "tying up" the nitrogen remaining after corn absorption in a nonleachable form, or both.

Time of fertilizer application, nitrification inhibitors, and applying the proper rate of fertilizer are factors being researched to evaluate fertilizer efficiency. (Efficiency is the pounds of fertilizer nitrogen required to produce a bushel of corn grain.) Increased efficiency (less fertilizer nitrogen required per bushel of grain) would mean that less fertilizer nitrogen would have to be added to attain a specified corn yield. The greater fertilizer efficiency would result in less residual nitrogen being in the soil after corn harvest. The factors we are studying would be expected to affect fertilizer efficiency by affecting the amount of nitrogen that might be "lost" prior to the time it is absorbed by corn.

As discussed earlier, there may be considerable nitrogen remaining in the soil after corn harvest at the most profitable rate of added fertilizer nitrogen. This residual nitrogen may not necessarily enter stream water, even if it remains in the inorganic form, but it could potentially contribute nitrate to streams. If the residual inorganic nitrogen is "tied-up" in organic form though, it will not enter streams because it is essentially immovable in the soil. One of the things we are researching is the use of rye to absorb nitrogen that remains after corn. The rye is seeded in corn prior to harvest, and should provide nitrogen-absorbing plants on the soil during fall and winter months. In addition to lowering the inorganic nitrogen content of the soil, the rye would lower the water content of the soil by transpiration. This means that for a given amount of rainfall less water would move through the drier soil profile with rye than the wetter profile without rye. This is to say that with rye there would be less water available for leaching nitrate from the soil.

Before a system such as the one using rye would be feasible for farmer adoption it must first be shown that our present system contributes substantial nitrate to water and that the rye system would reduce the amount. The rye system would probably not be adopted unless it is shown to be definitely needed because it would prevent fall plowing. Also, there obviously would be a cost associated with seeding the rye.

N Movement in Soil

Tile Studies. We have sampled water for three years from tiles that drain farmers' fields. The water was initially sampled for both nitrate and ammonium forms of nitrogen. Only very small concentrations of ammonium were found, so this analysis was discontinued. Concentrations of nitrate-nitrogen in the water are given in Table 1.

In 1969 and 1970, the average concentration of nitrate-nitrogen was greater than 10 parts per million during March, April, May, and June. During these months, 70 to 80 percent of the tiles had concentrations greater than 10 parts per million. There was a wide range of concentrations between the lowest and highest tile water sampled. The 1971 samples had a lower average concentration than did samples taken the two previous years.

Table 1. Monthly Lowest, Highest, and Average NO_3-N Concentration in Water From 10 Farmers' Tiles and the Percent of the Tiles That Were Greater Than 10 p.p.m. NO_3-N, 1969-1971

Variable	p.p.m. NO_3-N during: March	April	May	June	July	Oct.	Nov.
				1969			
Lowest tile	3.2	4.0	3.1	...	...	2.6	...
Highest tile	14.3	15.0	15.1	...	...	13.9	...
Average	10.0	10.5	10.9	...	...	7.4	...
Percent of samples greater than 10 p.p.m.	70	70	70	...	...	20	...
				1970			
Lowest tile	...	4.1	3.8	3.1	...	1.5	1.5
Highest tile	...	13.3	14.0	14.9	...	12.0	14.1
Average	...	10.5	10.9	11.7	...	8.4	8.7
Percent of samples greater than 10 p.p.m.	...	80	80	80	...	20	30
				1971[a]			
Lowest tile	2.2	1.7	1.6	...	2.3	...	...
Highest tile	14.0	11.2	11.5	...	14.7	...	...
Average	9.1	7.5	9.0	...	9.1	...	...
Percent of samples greater than 10 p.p.m.	50	20	60	...	50	...	...

[a] The values given in the table are for the same 10 tiles for which 1969 and 1970 data are given. Eight additional tiles were sampled in 1971. The average p.p.m. NO_3-N for the 18 tiles was 9.1, 8.5, 8.9, and 10.6 for March, April, May, and July respectively.

Because of the difficulty in tracing the tile and hence determining the land area drained by a particular tile, we are now unable to give the fertilizer and cropping history for each tile. Nevertheless, based on the behavior of nitrogen in soil, we would expect the concentration of nitrate-nitrogen to be greater in water draining from a field with a high rate of fertilizer nitrogen than in water draining from a field with a low rate of fertilizer nitrogen, other things being equal.

Of the total nitrate in the tile water, we are unable to say what percent came from fertilizer and what percent came from other sources.

In years of low, normal, and high rainfall in most of Champaign County, 3.39, 4.75, and 7.06 inches of water respectively pass through the soil and later enter streams. (Walton, W. C. 1965. Ground-water recharge and runoff in Illinois. Illinois State Water Survey, Urbana, Report of Investigation 48.) Using these values of drainage water and the average concentration of nitrate-nitrogen for March through June for all three years, we calculated the pounds of nitrate-nitrogen per acre in drainage water. The calculated data are given in Table 2. Nitrate-nitrogen in drainage water varied from 2.3 pounds per acre, based on the tile water with the lowest concentration in a low-rainfall year, to 21.9 pounds per acre for the highest tile water in a high-rainfall year. In a normal rainfall year and using the average nitrate-nitrogen of all tiles, the nitrate-nitrogen in drainage water was 10.8 pounds per acre per year.

Table 2. Amount of Nitrogen That Would Be Expected To Leach From Soil Into Streams During Years of Low, Normal, and High Rainfall in Champaign County

Variable	NO_3-N in tile water, p.p.m.	NO_3-N entering stream from soil Low rainfall year	Normal rainfall year (lb./A./year)	High rainfall year
Lowest tile	3.0	2.3	3.2	4.8
Highest tile	13.7	10.5	14.8	21.9
Average of all tiles	10.0	7.7	10.8	16.0

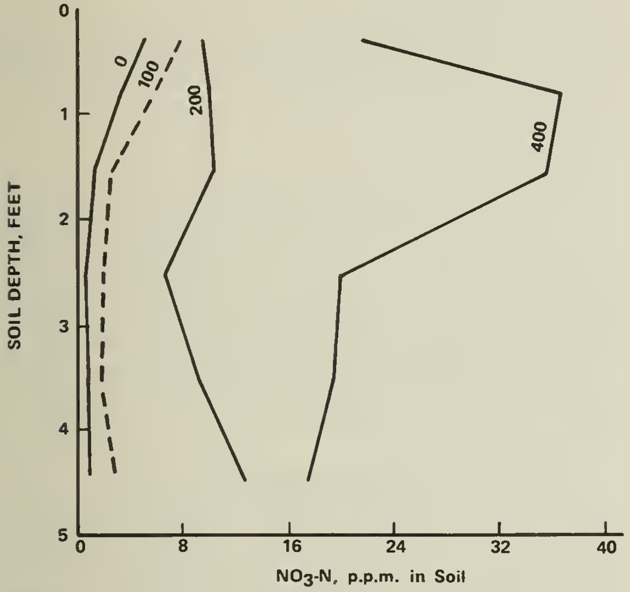

Figure 4. Nitrate nitrogen in the soil on November 11, 1971, where fertilizer nitrogen had been fall-applied to corn. Numbers on the curves are pounds of nitrogen per acre per year. Nitrogen had been applied for three years, but the 1971 application had not been added prior to sampling. (Data of A. A. Bomke.)

Soil Studies. Fertilizer nitrogen added in excess of corn's needs would be expected to increase the nitrate concentration in the soil and to leach downward in the profile. Nitrate-nitrogen concentrations are given in Figure 4 for four rates of fertilizer nitrogen added for three years to corn at Urbana. Residual nitrogen in the soil increased as the rate of fertilizer nitrogen increased. Soil nitrogen was only slightly increased with 100 pounds added per acre per year, but there was a considerable increase with 400 pounds of added nitrogen. We know of no farmer who applies as much as 400 pounds of nitrogen per acre. Nevertheless, the data do indicate that nitrate will leach through the soil and may enter water supplies if rates of fertilizer in excess of plant needs are added.

Summary

Crops contain more nitrogen than any other essential element. Large quantities of nitrogen are "hauled to the barn" in harvested crops. Illinois soils are incapable of supplying the nitrogen required for high yields of nonleguminous crops like corn. Fertilizer nitrogen is added to increase the amount of nitrogen in soil water that will be available for crop use. In 1940 only 1 percent as much fertilizer nitrogen was added as was removed by crops. But by 1966 the situation had reversed, and in 1969 Illinois farmers added 29 percent more nitrogen than was "hauled to the barn."

Corn is the big remover of nitrogen. Considerable nitrogen has to be in the soil for only about four months for corn culture. Research is looking for a way to keep nitrogen low during the eight months when corn is not growing.

The nitrate content of some tile water has been about 40 percent higher than the standard set for infants by the United States Public Health Service. Nitrate in other tiles has been 70 percent lower than the standard. Data indicate that nitrate will leach through the soil and may enter water supplies if rates of fertilizer are added in excess of corn's needs.

Nitrate Levels and Possible Sources in Shallow Wells

In the spring of 1970, as a result of some unexplained baby pig deaths on farms in Washington County with high-nitrate water supplies, Smith, Hill, and Walker (1970) conducted a survey of 242 groundwater and 72 pond-water samples collected by farmers. Of the 242 groundwater samples 213 were from large-diameter dug or augered holes ranging in depth from 6 to 30 feet. They found that 156 dug wells (73.2 percent) produced water containing more than 10 p.p.m. nitrate nitrogen. They also found that only four drilled wells (13.8 percent) and no farm ponds carried more nitrates than the public health limit.

High nitrate levels in shallow wells of central and southern Illinois are not a new problem. Weart (1948) made a study of 5,660 samples of water from private water supplies of all types and from all sections of the state. He found that 20 percent had a nitrate-nitrogen content of more than 10 p.p.m. (the public health limit). This included a large number of samples of low nitrate content from northeastern Illinois. He found that in Sangamon County more than 40 percent of the rural wells tested above the 10-p.p.m. level, while in Clinton County 75 percent failed to meet this standard.

In the winter of 1970-71 a research project was begun to determine the source of nitrates in shallow wells and to determine the suitability of farm ponds as an alternative water supply. This paper will present the status of our research to determine the nitrate source.

The first step in studying the source was to select some farms where it seemed reasonable to hypothesize that there was a single primary source and then test this hypothesis with a field investigation.

Farms Selected

Two farms were selected for study in 1971. The first farm selected consisted of a farmstead occupied by a tenant, while the owner farmed the land. Only the house with a few outbuildings remained and there had been no livestock on this farmstead for 10 years. We will refer to this as farmstead A.

Farmstead A had a dug well lined with brick, a depth of 28 feet, and a diameter of four feet. There were cracks in the well near the ground surface. This well was included in the spring 1970 survey of Smith, Hill, and Walker and tested 85 p.p.m. nitrate nitrogen.

The human wastes from the family on farmstead A were divided. Wash water was discharged at a point near the house and 170 feet upslope from the well, while a septic tank drain ended at a point 75 feet upslope from the well. We hypothesized that the septic tank was the primary source of nitrates for the well of farmstead A.

Farmstead B had a brick-lined dug well with a depth of 22 feet and a diameter of five feet. The well was located 10 feet from the barn and livestock yard with the septic tank seepage pit at a distance of 200 feet. The spring 1970 survey of Smith, Hill, and Walker tested this well at 88 p.p.m. nitrate nitrogen.

We will confine the remainder of our discussion to farmstead A in this report. Research is currently being conducted to analyze the source of nitrate nitrogen for the well on farmstead B.

Description of Study

An exploratory drilling study of both farmsteads was conducted in May and June of 1971. Several holes were drilled and samples were collected for a soil nitrate analysis. In addition, field notes were maintained of the material occurring in each hole. The pattern of exploration was along two axes which intersected in the farmstead.

After the initial study farmstead A was instrumented in more detail for a record of the groundwater surface, and for a record of the chlorides and the nitrates in the groundwater.

Fifty-eight observation wells were installed on farmstead A with nine additional wells in the bordering fields. Most wells were installed in pairs, with one well near the bottom of the zone of highest nitrates while the other was located at the top of this zone. The zone of highest nitrates was determined in the field with the Bray (1945) color test.

Observation wells served also as sampling tubes and consisted of ¾-inch PVC plastic pipe with six inches of one end slotted by a hacksaw. This slotted end was covered with a 50-mesh window screen. The pipe was installed in 2½-inch holes that were either augered or formed with a split tube sampler. The screened end of the pipe was packed with coarse-textured sand to a point 6 inches above the screen. Bentonite was used for at least the next one-foot section of pipe to seal the sampling tip from seepage that might come in from higher strata.

Water samples were removed from the observation wells using a vacuum carry tank and a 1/8-inch plastic tube. Fifty milliters of water were wasted before a sample was collected for analysis. This procedure was used to prevent contamination of a sample with previous water in the tube.

A regular sampling program of the well water quality and water use was maintained through the excellent cooperation of the tenant. A water stage recorder was installed on the well of farmstead A to maintain a continuous record of water level in the well to compare with water use.

Report by Elbert Dickey, W. D. Lembke, T. R. Peck, and Glenn Stone, College of Agriculture, University of Illinois at Urbana-Champaign, and W. H. Walker, Illinois State Water Survey.

Findings During 1971

Farmstead A with the location of two lines of exploratory drill holes is shown in Figure 1. The field analysis of the soil in each hole showed that the entire area of farmstead A and surrounding land is underlain with shale which becomes very slowly permeable at a depth of from 12 to 15 feet from the surface. We concluded that, although the well was constructed to a depth of 28 feet, very little water came into the well below 15 feet.

The slow permeability of the aquifer was also demonstrated by the water yield from the well. In September 1971 with the water level in the well at a depth of 12 feet and the water table 10 feet from the well at a depth of eight feet, the water yield was four gallons per hour.

The actual depth to the shale seemed to remain quite constant over the area near farmstead A, indicating that the topography of the shale corresponded closely with that of the ground surface.

In the vicinity of trees, roots were visible to a depth of six feet in the exploratory holes on farmstead A. It was clear that on much of this soil the aquifer carrying water to the well and the surface horizon supporting plant growth were the same.

The total nitrates in the soil down to the 12-foot depth were analyzed and were found to increase greatly in the vicinity of the farmstead as shown in Figures 2 and 3. Figure 2 shows the increase in nitrates along a north-south line while Figure 3 shows the increase in nitrates along an east-west line.

The average nitrate nitrogen per foot of depth in the upper 12 feet increased from less than 10 p.p.m. on an air-dry soil weight basis on all holes away from the farmstead to as high as 60 p.p.m. on the farmstead itself. There also appeared to be a build-up of nitrates in this 12 foot layer of soil as the farmstead was approached from any direction.

A nitrate analysis of the soil samples taken in the process of installing observation wells on the farmstead substantiated that high levels of nitrate exist in the soils of the farmstead area. Figure 4 shows a nitrate map of the farmstead constructed from data taken in July of 1971.

An analysis of the total nitrates on the farmstead in the 12-foot soil layer was made using the map of Figure 4. The analysis was made by determining the area between each nitrate contour and assigning this area to the average nitrate level between contour lines. The total values thus obtained were added together for the entire farmstead. Using this technique, the total nitrate nitrogen in the 12-foot surface layer of farmstead A was determined to be 1,000 pounds greater than the total nitrate nitrogen in a corresponding area of the surrounding field outside the farmstead.

There was a difference observed in the distribution of soil nitrate with depth on the farmstead as compared with the field area. One exploratory hole on the farmstead is shown in Figure 5. This hole was drilled in June of 1971. The nitrate level increased with depth to some level below the root zone of plants.

One distribution of nitrates with depth for field soil is shown in Figure 6. These data also were collected in June of 1971. The nitrate level was high in the surface and decreased rapidly to the three-foot depth. Figure 7 shows the distribution of nitrates with depth in an old barnlot in Missouri investigated by Keller and Smith (1967). There had been no cattle present for 10 years. The distribution is similar to Figure 5 in that there is an increase in depth to about nine feet.

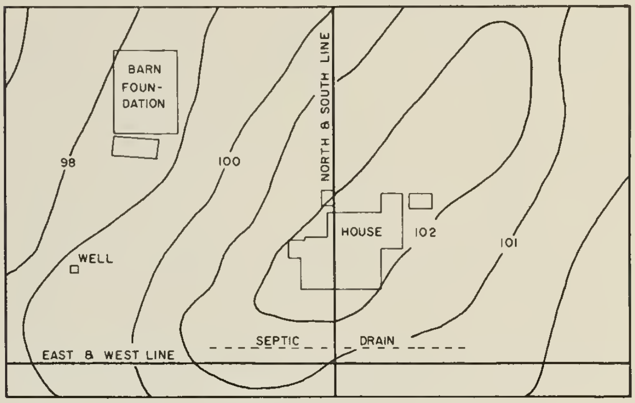

Figure 1. Farmstead A showing location of lines for exploratory holes to determine nitrates in the soil profile.

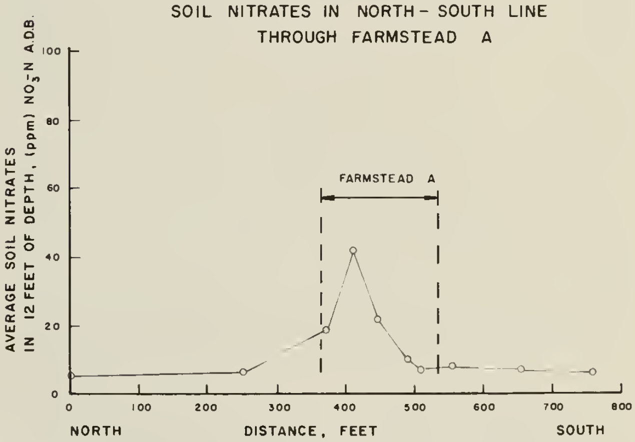

Figure 2. Soil nitrates in the first 12 feet of depth along the north-south line shown in Figure 1.

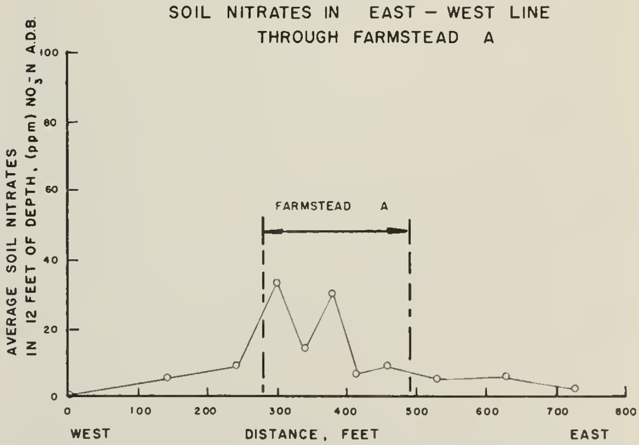

Figure 3. Soil nitrates in the first 12 feet of depth along the east-west line shown in Figure 1.

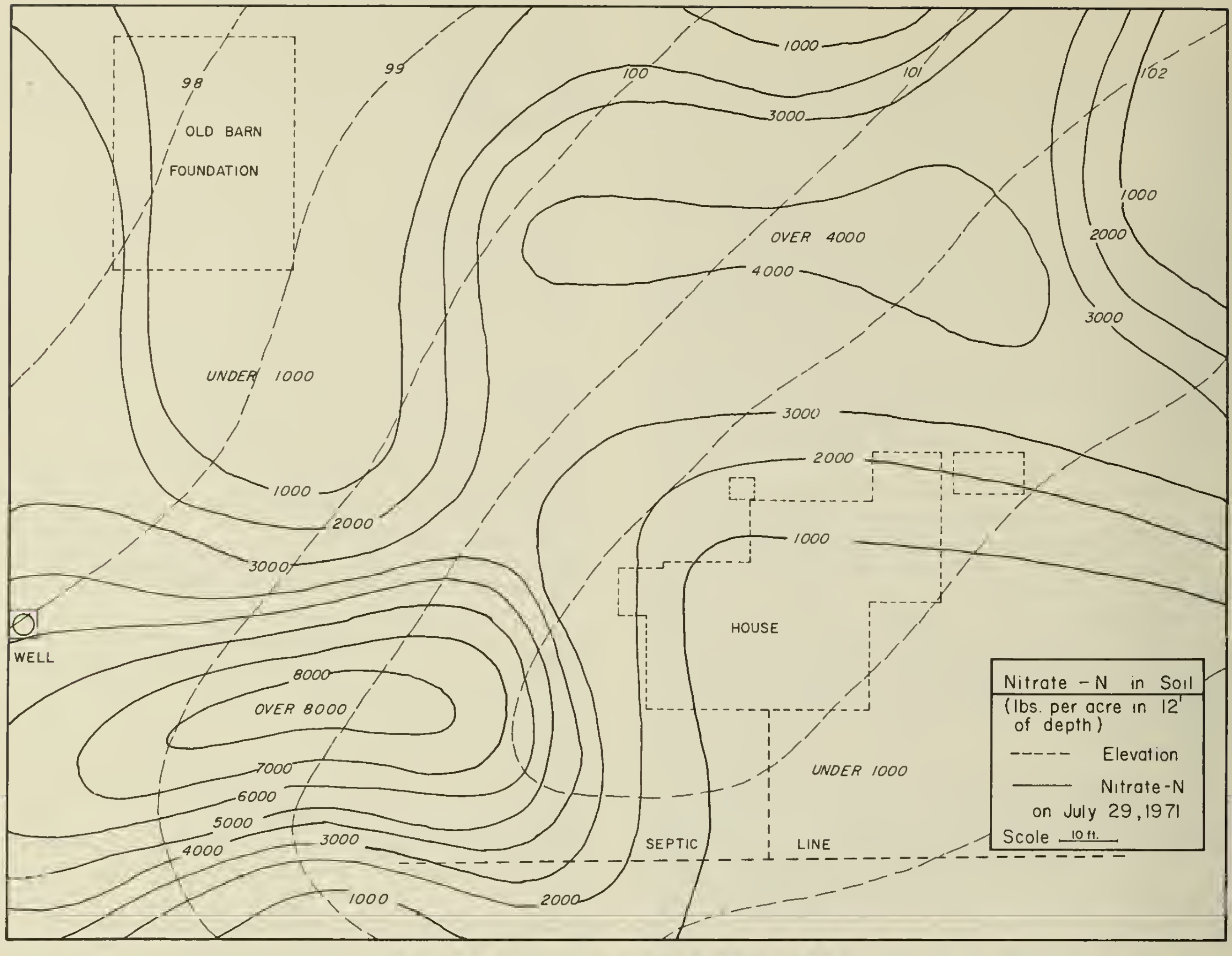

Figure 4. Nitrate nitrogen in the soil of farmstead A.

Water-level readings, nitrates, and chlorides have been determined from the observation wells on farmstead A at intervals of at least once a month since August 1, 1971.

Figure 8 shows a comparison of the nitrate level in the soil on an air-dry weight basis from samples taken in July, 1971 and the nitrate level measured in the soil water solution as measured in samples taken from observation wells on October 6, 1971. Each point represents a sample from an observation well. There appears to be a straight-line fit of the data. Three points depart from the straight line to a considerable degree: A123, C33, and C151. The first 2 points were from the only observation wells with highly variable nitrate levels in strata near the sampling point. C151, however, is from a uniform strata. The nitrate content of samples taken from C151 increased from the time the well was installed in July. C151 is located within 10 feet of the end of the septic tank seepage line shown in Figure 4.

The nitrate ion is very mobile in the soil water solution, but chloride ions also move freely. Chlorides are commonly found in the decomposition products of animal waste and consequently have value in determining a pollution source.

If the primary source of nitrogen was fertilizer or rainfall, there should not be any correlation between nitrates and chlorides in the soil water solution. On the other hand if the primary source of nitrates was from animal or human wastes, there might be some increase in chlorides with an increase in nitrates in the soil water. Since the leaching of chlorides could precede nitrification and subsequent leaching of nitrates, the specific relation between nitrates and chlorides in the groundwater may vary depending on a number of factors. Figure 9 shows a plot of nitrates against chlorides in the soil water at the 12-foot depth on farmstead A. As in Figure 8 each point represents a sample taken from a different observation well on the farmstead. All samples were taken on the same day. Figure 9 shows that with an increase in nitrates in the soil solution there is a corresponding increase in chlorides. This relationship strengthens the hypothesis that animal or human waste is the source of nitrates on farmstead A, but does not help us determine whether the source was a septic tank, former livestock pen, an old manure site, or an old privy site.

Figure 10 shows the change in nitrate content of the water from the well on farmstead A through September

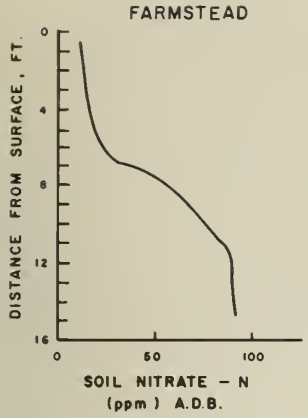

Figure 5. The distribution of soil nitrates from the surface to the 12-foot depth in one exploratory hole on farmstead A.

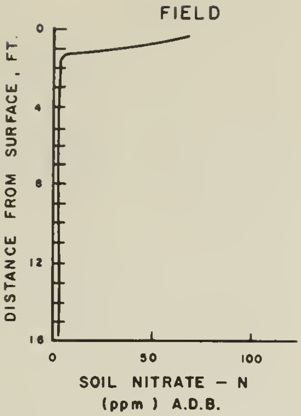

Figure 6. The distribution of soil nitrates from the surface to the 12-foot depth in one exploratory hole on a field adjacent to farmstead A.

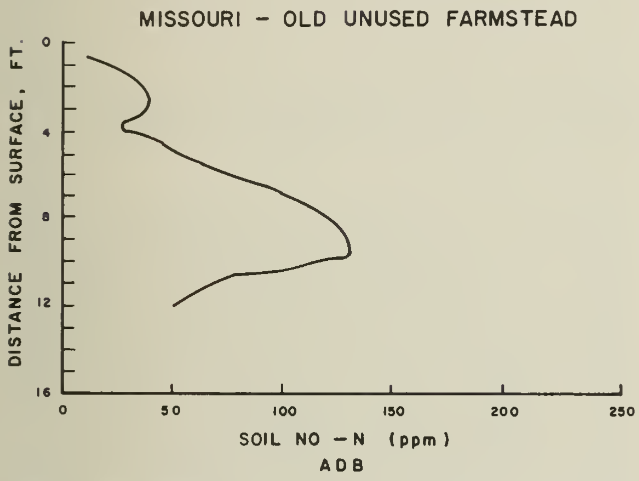

Figure 7. The distribution of soil nitrates from the surface to the 12-foot depth in an exploratory hole in an old barnlot in Missouri. Keller and Smith (1967).

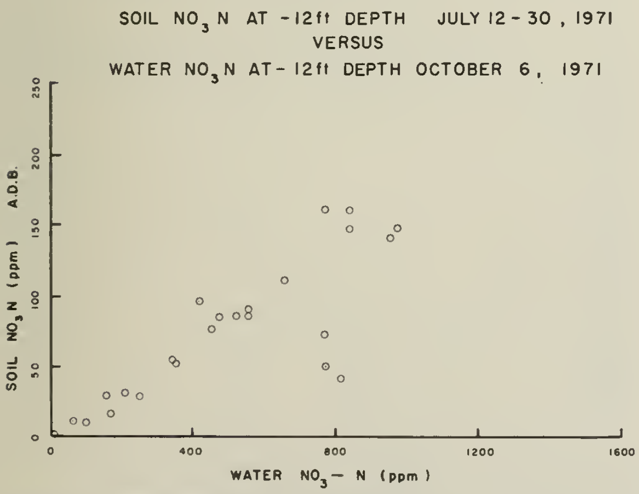

Figure 8. A comparison of nitrates measured in the soil on an air-dry basis with nitrates measured at the same depth in an observation well.

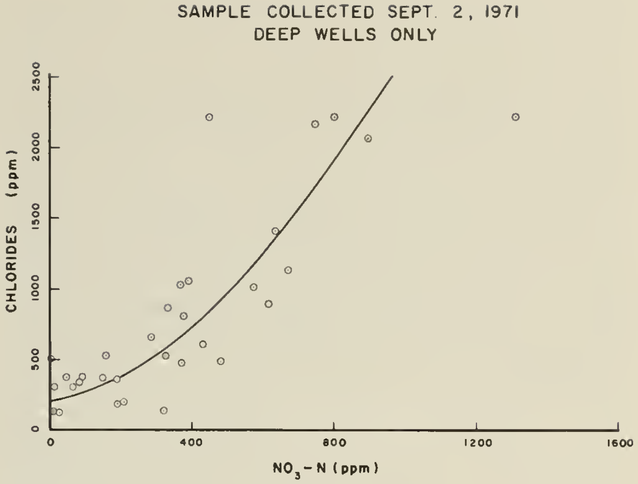

Figure 9. A comparison of chlorides with nitrate, in water sample, taken on the farmstead at the 12-foot depth.

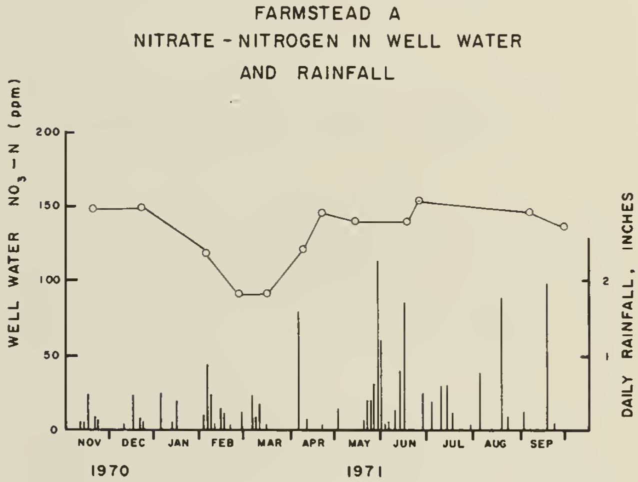

Figure 10. The change in nitrates in the well for farmstead A during one year. The vertical bars represent daily rainfall.

1971. The rainfall during 1971 is also plotted on the same graph. The dilution effect that occurred with recharge resulting from rainfall and very little evapotranspiration is evident with the decrease in nitrate level between February and late April.

Water-level readings in observation wells on the farmstead during 1971 showed that there was a continued high water table level in the vicinity of the house. This water table sloped downward toward the well. The high water-table level on the farmstead was contributing to the well in 1971. Since the farmstead also contained a high level of nitrates, we have concluded that in 1971 the primary nitrate source in the well originated on the farmstead.

The septic tank on this farmstead had been in use by a family of five for three years before 1971. Using the average values given by Harmeson et al. (1971) for a total nitrate nitrogen in human waste of 0.025 pounds per day per person, this family had a possible total of 140 pounds of nitrate nitrogen delivered through the septic tank disposal system. Since there were 1,000 pounds more nitrate nitrogen on the farmstead than on the surrounding field, we must conclude at this time that the major part of the excessive nitrates on the farmstead resulted from sources other than the septic tank.

At the present time we are also making measurements of the total nitrogen in the septic tank effluent to make adjustments in the pounds of nitrate per day per person for this situation.

Our present research is being directed toward finding what can cause large concentrations of nitrates to develop in the soil. We are particularly concerned that in a humid region where we ordinarily expect a net downward movement of water during each year, we are getting an accumulation of soluble salts such as nitrates and chlorides at deep levels in the soil while the surface layers are relatively free of these salts.

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Costs of Alternative Sources of Farm Water

After air, water is the most important substance for man's survival. Most of us have considered water, like air, to be a free good—to be taken as needed in any quantities desired. Today, this is not always the case. Water has become an economic good, a scarce resource, in part because of the vast increase in the daily per capita consumption of water but also because some of our water sources have become contaminated to the point that they are unusable.

Today, we can make water available anywhere it is wanted and upgrade its quality as much as necessary. The technology is available, so now it is just a matter of economics: How much are the users willing to pay at a given time and place? People who are used to thinking of water as a free good resist putting a price on it at all, but many people in various areas of Illinois, who must buy and haul water to meet their daily needs, are quite aware that substantial costs are involved.

In order to examine the costs of water from various sources, a study was initiated in the Washington County, Illinois, area. The water supply situation there has been the focus of widespread concern, as evidenced by a number of research projects conducted there in recent years. The specific area in this study is approximately 10 square miles, located to the north and east of the Village of Hoyleton in the northeast corner of Washington County. This area was selected because several farmers in this area had expressed concern to the county extension adviser about their water supplies. The farmers felt that poor water quality was contributing to disease in the swine herds and to breeding problems with dairy cattle. Quantity was also a problem, with some farmers hauling as much as 20,000 to 30,000 gallons each month to meet their needs.

The 38 residents in the study area were interviewed about their present water supplies, uses, and requirements. Table 1 summarizes their responses. Nearly all of the 38 reported they used two or more sources to meet their daily water requirements; the few who reported only one source were farmers or other rural residents with few or no livestock, whose primary demand was for household use. Over 70 percent of the respondents reported at least one pond on their property; a few indicated they had a second one.

Table 1. Present Water Source and Use Summary

	Deep well	Shallow well untreated	Shallow well, treated	Cistern	Hoyleton	Pond	Combination
Human consumption	1	15	2	17	2	0	1
Other household uses	0	6	1	21	2	0	8
Milk house	0	3	5	2	1	0	0
Watering dairy	0	0	0	0	0	9	3
Watering other livestock	1	10	0	1	0	7	3

Remarks by C. L. Moore, graduate research assistant, Department of Agricultural Economics, University of Illinois at Urbana-Champaign. The research reported in this paper was supported in part by funds provided by the U.S. Department of the Interior as authorized under the Water Resources Research Act of 1964, P.L. 88-379, Agreement No. 14-31-0001-3513.

It is interesting to note that about half of the residents use wells as their source of drinking water and about half use cisterns. Those who drink cistern water do so because the wells contain so much nitrate; those who use well water feel that, because of the bacterial contamination of most cisterns, they will take their chances with the wells, nitrate and all. To determine just what the quality of the water was, samples were taken from 35 of the 38 residents and analyzed at the Regional Diagnostic Laboratory at Centralia, Illinois. These samples were from 34 shallow wells, 1 dug well, 21 cisterns, and 8 ponds.

All 8 ponds tested were found to be free from nitrate contamination (0 p.p.m. NO_3), as were all 21 cisterns. Not one cistern, however, was rated satisfactory in terms of coliform and other bacteria *(5)*. Coliform counts ranged from 4 per 100 ml. to excessive levels. Interestly, several of the cisterns contained water that had been hauled in presumably "pure" tank trucks or wagons from the nearby village water system, which seems to indicate that the cistern itself is the source of contamination. Poor construction, improper maintenance, and obsolescence are the probable causes of contamination in most cistern supplies. Of the 34 shallow wells, 26 contained nitrate above the 45 p.p.m. level *(5)*, and only one of the 26 shallow wells that were analyzed for coliform bacteria was considered satisfactory. The one drilled well in the area had 57.2 p.p.m. nitrate and was not analyzed for bacterial content. Thus, it seems that both the cisterns and the wells are dubious sources of drinking water.

Residents were also asked how much water they needed daily, based on the maximum number of livestock that would be on the farm, the number of persons in the household, and any other uses for water. According to their responses, the residents were placed into three general categories. Those whose primary demand for water was for household use—quality I water—comprised the first category; these could be either persons who live in the country and work in the city or grain farmers with few or no livestock. The second category consisted of farmers who milk more than 25 head of dairy cattle. These farmers required large amounts of quality I water for the milkhouse as well as their homes; they also, obviously, had large requirements for water to water their livestock (quality II water). The third grouping was a general livestock category: these farmers needed lots of quality II water but only enough quality I water for their households. For the purposes of this study, the water requirements within each category were averaged, as shown in Table 2.

Table 2. Water Requirements by Category of Farmer in Gallons per Day

	Quality I		Quality II	
Category	Mean	Range	Mean	Range
Rural resident	150	50-300	13	0-90
Primarily dairy	1,165	600-2,500	1,722	900-3,500
General livestock	240	100-625	1,495	60-7,400

To determine how the residents of the study area could fulfill their water requirements, the most realistic alternatives were considered: the present sources (cisterns, wells, and ponds), combinations of the present sources, augmentation by hauling from the village of Hoyleton, and some type of a pipeline system that might hook into the system at Hoyleton.

Present sources, as mentioned earlier, are of questionable quality. The reliability of these sources is also relatively unsatisfactory; when the wells, cisterns, and occasionally ponds "go dry," the deficit must be made up by hauling water from Hoyleton. During the 14-month period from September, 1970, through October, 1971, 350,925 gallons of water were hauled to the study area from Hoyleton; this was 33.8 percent of all water hauled from Hoyleton during the period (1,037,135 gallons), an indication of the severity of the problem. Some farmers must haul so much and so often that they own their own hauling equipment—usually a closed tank on a wagon or truck bed. Bulk water from Hoyleton costs $1.60 per thousand gallons, and when gasoline, labor, maintenance, and inconvenience are considered, hauling costs are about $5 per thousand gallons. Commercial bulk milk haulers also haul water upon request, usually charging $10 per 2,000-gallon load.

In order to determine what source or combination of sources can provide the needed water at the least cost, a criterion for evaluating the alternatives is needed. The most relevant economic theory is capital budgeting theory (discussed in *1, 2,* and *3*), and the criterion used in this study is net present value. This criterion takes into account that there is a time preference for money—that is, a dollar is worth more today than a dollar at some time in the future.

As an example, the present value of $100 payable in 2 years can be defined as that quantity of money necessary to invest today at compound interest in order to have $100 in 2 years. Assuming that the interest rate is 8 percent compounded annually, the present value of $100 would be only $85.73.

	Value at beginning of year	+ 8 percent interest	= Value at end of year
First year:	$85.73	+ .08(85.73)	= $92.59
Second year:	$92.59	+ .08(92.59)	= $100.00

Thus, to determine which investment is best, calculate the present values of the returns and costs (both immediate and future) associated with each investment at the appropriate cost of capital, find the difference, and select the investment with the highest net present value. This evaluation is strictly on a dollar basis, of course; actual decisions are usually influenced by subjective, noneconomic factors as well.

If two investments have same present value for returns, obviously only the present value of the costs need be compared. In this study, it is assumed that each source or combinations of sources has the same return—that is, each fulfills the water requirements on a given farm or type of farm.

While not all of the analysis has been completed for the study, this paper will compare the present values of costs for shallow wells, ponds, and hauled water for a typical general livestock farmer in the study area.

To evaluate these alternative investments, certain assumptions must be made about the length of productive life of the investment, the appropriate cost of capital to be used as the discount rate, and the length of time involved. For the purpose of the presentation, the cost of capital will be assumed to be 7½ percent, the approximate cost of mortgage capital; this is only an assumption and must be modified whenever appropriate. The expected useful life of the alternatives and associated equipment is 20 years, all present values are extended to 20-year periods by including replacement of the equipment where necessary. The average daily water requirement for a general livestock farmer, the amount assumed to be the "return" from each investment, is 240 gallons of quality I farm water and about 1,500 gallons of quality II water.

The cost of well construction for large-diameter shallow wells is estimated by the equation W.C. = 30 + 11.52d, where W.C. is the well cost in 1969 dollars and d is the depth of the well in feet *(4)*. Given that the average depth to bedrock in the study area is 27 feet, the cost of well construction there is computed to be $341.04. Increasing this by 5 percent to express the cost in 1971 dollars gives an initial cost of well construction of $358.09.

The pumping system for a well of this type was estimated in 1969 to cost about $520; plus 5 percent, this is $546. This includes the pump, the adapter unit, the pressure tank, and all associated piping and wiring costs. The expected useful life of the well and the pumping system is 20 and 10 years, respectively, so the pumping system will have to be replaced at the end of 10 years; estimated annual maintenance costs for the entire setup are about $10. As detailed in Table 3, the present value of the costs of a shallow well system is $1,270.94. Because of the relatively low yield of this type of well (less than 3 gallons per minute), and because of the nature of the soil and other geological conditions in this area, it is general practice to have more than one well.

Table 3. Present Value of a Shallow Well System

Time	Item	Present value
t_{1971}	Well	$ 358.09
t_{1971}	Pumping system	546.00
t_{1981}	Pumping system	264.91[a]
t_{1971}-t_{1991}	Maintenance	101.94[b]
		$1,270.94

[a] Present value of the replacement pumping system = the amount of money that will be worth $546.00 in 10 years at 7½ percent compound interest.

[b] Sum of the amount of money that will be worth $10 today plus that which will be worth $10 next year at 7½ percent compound interest, and so on for each of 20 years.

Choosing the pond as an alternative source of water means considering how the water will be used. If the water is intended to be used only for livestock, for example, no treatment facilities would be needed; for household use, however, water treatment is necessary. The hypothetical "typical" pond (untreated) in this study incorporates some of the features of both a dug out type and an embankment type. The excavation charge was assumed to be 50 cents per cubic yard, and the local soil conservation office estimated the total cost for spillway construction at $400. The SCS also suggested an annual maintenance cost of $50 for the pond and spillway. The pumping system for the pond is similar to that of the well but requires a different size and type of pump and additional piping; the estimated initial cost is $625. Maintaining water quality (at quality II) would require that the pump be replaced or undergo major repairs every 5 years, with such services estimated to cost $250. Yearly maintenance costs for the pumping and distribution system would be about $10. Table 4 gives the present value of the costs for this system. Because as much as 50 percent (up to $2,500) of the cost of the pond construction can be shared with the SCS when the stipulated conservation practices are followed, the initial cost of excavation and spillway construction could be reduced by $1,396, thereby reducing the present value of an untreated pond to $3,012.59.

Table 4. Present Value of Pond System

Time	Item	Present value
t_{1971}	Excavating	$2,392.00
t_{1971}	Spillway	400.00
t_{1971}	Pump system	625.00
t_{1976}	Pump system	174.14
t_{1981}	Pump system	121.30
t_{1986}	Pump system	84.49
t_{1971}-t_{1991}	Maintenance	509.72
t_{1971}-t_{1991}	Maintenance, pumping and distribution system	101.94
		$4,408.59

When the pond water is to be used in the household, a chemical treatment unit is needed. The estimated cost of a unit that can supply the quantity of quality I water required by the general livestock farmer is around $1,400, with an expected equipment life of about 10 years. Major equipment replacement or repairs may occur every 5 years, with such repairs estimated at $250 on the unit selected for this study. Yearly maintenance costs would be about $50 for this system. The present value of the associated costs for treated water is detailed in Table 5. By adding this amount to the cost of the pond ($3,012.59), we get a present value of $5,860.21 to get drinking water from the pond.

Table 5. Present Value of Pond Treatment System

Time	Item	Present value
t_{1971}	Total unit	$1,400.00
t_{1976}	Major repair	174.14
t_{1981}	Total unit	679.27
t_{1986}	Major repair	84.49
t_{1971}-t_{1991}	Maintenance	509.72
		$2,847.62

The general livestock farmer's requirement for both quality I and quality II water is 1,735 gallons daily, or 633,275 gallons per year. Hauling all of this at the rate of $5 per thousand gallons would cost $3,166.38 per year. The present value of this cost, incurred each year for 20 years, is $32,279.34.

The present values of the costs of the alternative water sources presented here can be summarized as follows: shallow well—$1,270.94; untreated pond—$3,012.59; treated pond—$5,860.21; hauling—$32,279.34. From these figures it appears that the shallow well has the lowest cost; if, in fact, more than one or two wells are needed, however, the ranking would be changed. Moreover, since the water coming from many of these wells is of unsatisfactory quality, and would most likely require treatment, the ranking may again be altered. Not every alternative has yet been evaluated, but this paper has tried to give some feel for the magnitudes of the costs involved and an illustration of the analytical procedure.

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Human Interaction With the Man-Made Environment

Alone . . . silence . . . darkness . . . neither hot nor cold . . . untouched by sights, sounds, or smells. This is man without an environment.

But man cannot live without an environment. Man cannot remain sane in a limited environment of darkened cells, his senses devoid of stimulation, his mind filled with a series of abstract thoughts unrelated to any outside stimulation. The mind loses its concept of space and time and its sense of balance. Without an environment, man loses his sense of belonging and identity.

Human interaction with the physical environment is a phrase intended to express the relationship between an individual or a group of people and interior space and objects in which he works and lives, exterior spaces between buildings in which he lives and travels through, or larger geographical areas encompassing his life. Man in any of these categories affects nature, animals, and other men and they, in turn affect him. The physical environment is indivisible from people, both of which exist together in a state of constant reciprocal action and reaction.

Definition of the Problem

From the beginning man has faced problems with his environment. The first and most essential interaction focused on his efforts for survival and safety. But as he became more civilized and developed science and technology, his interaction with the environment became so vast and complex that today some people are questioning whether either man or the environment can survive.

Our task is to study human interaction with the physical environment and make use of our findings in reckoning with human and environmental management.

For example, the underlying unit of our total environment is the land. The term "land" suggests different things to different people, depending on their current outlook and interests. Land is thought of as the surface upon which life takes place, and it is considered a natural resource providing food, building materials, minerals, and energy resources. Because Illinois' high standard of life is credited to our possession of a rich land-resource base, it is imperative that current and future interactions of man and land be investigated. Such an investigation must be related to the world as we know it today. It can be divided into three categories—urban, rural, and suburban. These are the staging areas for human activity systems which in turn interact with population density, technology, migration patterns, economics, and political influences.

A "systems break" has reciprocal influences in all these forces of change and interaction. Therefore, environmental problems are more than dumping waste into streams, spewing noxious smoke into the air, or spraying with chemicals. It includes the products of man—things he has created to protect and shelter himself, to help him go faster and further, to communicate easier, to entertain himself, in short to give himself a better life.

The result is that restoration, conservation, and creative development of our environment has emerged as a key concern of this decade. The problems associated with this issue are man-created and must be solved by man. In our search for solutions, we must not ignore the role of man as a force changing the environment and as the recipient or victim of the physical environment. *Human interaction with the environment is a pivotal area to which all other environmental efforts must relate if relevance is to be achieved.* Yet, at the present time, knowledge is in inverse ratio to questions. This in part may result from the normal insulation of the many disciplines whose contributions are essential but are remote from day-to-day living and from the widening gap of incomprehension between science and culture. An interdisciplinary approach is difficult to organize but is essential to a successful research effort.

The lack of knowledge is also related to the federal government's lack of commitment to man-environment research. But with the shift of national priorities from

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Report of task group on human interaction with the physical environment: W. R. Nelson, Jr., leader, H. H. Alexander, R.W. Cramer, J. F. Evans, G. W. Hardiman, W. M. Keith, R. N. Salcedo, H. J. Schweitzer, and Theodore Zernich.

aerospace research to urban research, there is new hope that the federal government's role in man-environment research will assume significant new dimensions.

Overall View of Research Growth

A recent survey by Andrew Euston, architect in the Environmental Planning Division of the Department of Housing and Urban Development, shows that the funding of man-environment research has grown from virtually nothing in 1960 to close to $30 million in 1971. This shows progress, but as federal research figures go this is a tiny amount. It does, however, far exceed what private industry and universities are committing to this type of research. Indications are that support for man-environment research should grow dramatically during the seventies. Many groups, such as this task force, are gradually overcoming the growing pains of this new complex field by hammering out clearly defined goals and establishing effective ground rules for research that is meaningful in a scientific and social sense. The results will generate a greater number of proposals than have ever been offered.

A review of the research efforts now taking place in federal agencies indicates that currently the Department of Health, Education, and Welfare leads all other agencies in people-environment research. By contrast the Department of Housing and Urban Development research focuses more on the technology of building than on man-environment concerns. Nine other government agencies are sponsoring man-environment research. Among these is the Department of Agriculture where four of its five man-environment research efforts are directed at rural housing. These projects have been undertaken at various agricultural experiment stations at land-grant universities.

Programs at the University of Illinois

Here at the University of Illinois Agricultural Experiment Station, the task group on human interaction with the physical environment is organized as an interdisciplinary group including architecture, landscape architecture, interior design, sociology, fine arts, and communication. It has chosen to direct its efforts into two distinct but complementary programs. The first is the development of a research program on human behavior and response to the man-made environment. The second is a public education program. This program is based on the hypothesis that before government and private sectors will respond to man-environment considerations, the people must respond by demanding man-built environments more responsive to their needs.

The research proposals for this task group are still in the developmental stage. The process of establishing goals and developing research techniques has been long and difficult. Just the matter of communication between disciplines takes time. Nevertheless it is anticipated a package of at least three proposals will be presented for funding by June, 1972. The task group members George Hardiman and Theodore Zernich (Department of Fine Arts) are currently involved in an environmental analysis of dining facilities on military bases with the Corps of Engineers. Their goals, research techniques, and anticipated application of results closely parallel the research model being developed by the task group.

The public education program will be implemented in February, 1972. This program is a collaborative effort with the Cooperative Extension Service whose statewide field staff will implement the program on the local level. The following information gives an overview of the project:

Situation. In the next three decades, it is anticipated that the man-built environment will double. Before government and private developments will respond to the need for quality in design, the people must respond by demanding built environments responsive to human needs. This program focuses on the education of people to eliminate the apathy that tolerates blight, disorder, and ugliness within the community.

Objective. The objectives of this program are to create a problem awareness on the part of the general public; to motivate local people to undertake action programs for the improvement of the existing community environment; and to initiate local concern and demand for quality design in new projects that will acknowledge the human or social needs as well as the physical and functional aspects of the project. Finally, this program strives to generate local concern for the aesthetic impact of new developments on the community.

Program content. The project is structured around a color-sound film produced by the Cooperative Extension Service; a slide set with taped narration; and video-tape presentations prepared in the community to graphically identify local problems and present possible solutions. A 300-page workbook is also available for local leaders to use in developing local action programs.

The film, *A Place To Be Human,* explores problems of the community's man-made environment and suggests how individuals, groups, and local governments can work for a humanized and beautiful community environment. The slide set elaborates the theme established by the film and allows for a more detailed analysis of the potentials and opportunities for modifying and improving typical situations that exist in every community. The Community Design Workbook is for citizens and governmental officials who want to take action to improve their community. The workbook provides subject matter to help understand the problems that exist and describes the ways and means of implementing changes.

The video-tape presentation will be made through the use of portable equipment. In a matter of a few hours before a local meeting, a subject-matter specialist can film both good and bad situations in the community to help the audience better identify their own problems and develop plans to remedy them.

Extension Education and Public Service

A year has passed since our first Allerton Conference at which we attempted to determine the major environmental problems that affect food production and people. At that time, we listed the major research needs to which the College of Agriculture should direct its efforts.

The role of our specific task group, is to develop effective educational programs on environmental quality. Our emphasis is on disseminating research findings from the University of Illinois (and other research institutions) to people in the state and channeling major environmental problems to the appropriate research groups for answers.

From the first Allerton Conference, the extension education and public service task group developed the following recommendations for educational programs on pollution and environmental quality;

1. The Cooperative Extension Service should be directing its environmental educational program to a much broader audience. We must reach urban people to give them a better understanding of the effects and consequences of agricultural technology and explain how decisions made by the farmer will affect the quality and cost of food to the consumer.
2. The Extension Service should make available to legislators and agency personnel involved in formulating regulations all information it has that may aid the development of laws, regulations, and standards.
3. The Extension Service should use its organizational expertise in bringing together the appropriate citizen groups to help in the development of standards and regulations. It should then develop an educational program that will enable citizens to understand the standards and regulations once they are adopted.
4. Educational programs should be developed that will help farmers understand how to minimize pollution from soil erosion and from production practices such as fertilization and the use of insecticides and herbicides.
5. Three program areas for agricultural and nonagricultural audiences were suggested: (a) water supply; (b) human and animal waste disposal; and (c) solid waste disposal.
6. Youth programs should be organized with an objective of developing pride in the home and community.
7. Materials should be developed for use in elementary school programs to tell the story of food production and the place of fertilizers, pesticides, and technology.
8. The College curriculum should include courses for nonagricultural students so that they may better understand food production.

A program aimed at nonagricultural audiences is now being implemented in the Chicago area. A request from Carl Mees, Extension Chairman in Cook County, and a number of agribusinessmen, initiated the development of an 18-page booklet entitled, "How Food Production Affects the Environment." This publication was written to provide basic material which agribusinessmen could use in developing talks for service and civic clubs on environmental quality and agriculture. A condensed version of the booklet (Circular 1037, with the same title) was published for use as a handout to those attending the civic and service functions. Dr. Mees developed a brochure announcing the program and listing speakers available. This brochure was mailed to a select group of clubs which the agribusinessmen wished to reach in a one- or two-month period. The clubs, in turn, sent their requests to Dr. Mees, who arranged the programs. All our county Extension advisers have received copies of the booklet and brochure, and well over 10,000 copies of Circular 1037 have been distributed.

We are also developing slide sets on agriculture and environmental quality for the nonagricultural audience. One is on livestock waste. Topics for future sets are: laws and regulations; pesticides; plant nutrients; agriculture and the ecological system; air pollution; and sediment and erosion.

Our specialists and area staff will be presenting between fifteen and twenty major home economics lessons on environmental quality this winter. Specialists present lessons and provide mimeographed lesson outlines to leaders representing ten to twenty local units attending the special school. These representatives then present the lesson to their units.

The Agricultural Engineering Department employed a qualified agricultural engineer to make a study and issue recommendations on the needs for a special school on designing animal waste handling facilities, for private consulting engineers, EPA engineers, and Soil Conservation Service engineers.

The USDA Agricultural Stabilization and Conservation Service (ASCS), Soil Conservation Service (SCS), and the Farmers Home Administration (FHA) are developing a demonstration program for 1972 under the USDA "Environmental Thrust Program" in conjunction with Extension. This program deals with livestock waste handling facilities. We are asking counties to select one to six farmers who have animal waste problems and who are interested in finding solutions at this time. We will develop demonstration systems for use as an educational tool in solving the problems. SCS will provide the design; ASCS will provide cost-sharing under the Rural Environmental Program (REAP), and FHA loans will be acquired where appropriate. Extension will develop the publicity materials and arrange for public meetings for the agricultural people.

Extension will be continuing with many of its programs relating to environmental quality, such as the annual

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Report of task group on Extension education and public service: R. D. Walker, leader, C. A. Bock, K. R. Bolen, D. G. Jedele, W. R. Oschwald, and H. B. Petty.

sprayers' school; the pesticides dealers' and applicators' clinics; publication of a newsletter, "Plain Talk on Pesticides"; publication of a weekly situation report (listing threshold populations, natural enemy situation, effects of weather, control recommendations, etc., to be sent to all daily newspapers, radio and television stations, county Extension advisers, and 1,000 subscribers); swine and beef meetings; and agronomy meetings.

Legislative Implications at Federal Level

I'd like to begin my remarks today by telling you two things that I do not plan to discuss.

First, I will not offer you the standard chronicle of environmental horrors that is customary at the opening of an address such as this. This is a knowledgeable audience, which is doubtless as familiar with the grisly statistics as I am. And, moreover, I believe that the annual figures are so large that they have lost their capacity to shock us. Forty-eight billion cans, 26 billion bottles, six million pounds of mercury—these are numbers that dull the senses, and do not bring forth a satisfactory image of the problem.

Secondly, I speak as a legislator and public official and would not want to compete directly with the experts assembled here. I know you have heard progress reports from the eight task force groups that make up the College of Agriculture's Council on Environmental Quality, and I am sure that these distinguished researchers have a much greater command of the scientific facts and figures than I do.

What I would like to do today is to offer some broad observations—part fact, part philosophy, perhaps even part personal prejudice—on the overall question of our environment and the continuing crusade to rescue it from destruction. If I can stimulate—or provoke—you, I will have served my purpose.

It seems to me that each of the groups represented here—business (or perhaps I should say agribusiness), government, education, and technology—has a major role to play in any comprehensive plan for environmental management. Permit me to offer one Senator's thoughts on what these roles should be and how they relate to each other.

I will begin with business, to which I devoted a quarter-century of my life and which has had its knuckles rapped exceptionally severely by ecologists lately.

In my opinion, exhorting business to develop a more acute social conscience is an activity of limited value. This is not to say that business is unconcerned about the physical and social environment in which it functions, yet the fundamental force operating on business is the profit discipline. Business must make money if it is to satisfy its stockholders and survive.

Herbert P. Doan of the Dow Chemical Company, which perhaps has absorbed more of the activists' ire than any other corporation, offers what I think is a completely reasonable view of the role of business in environmental protection. He says: "Industry's responsibility is to create products and services within the limits of government policy and public attitudes. With the needs identified and proper incentives, industry can serve society at low cost."

In my judgment, we can most effectively enlist business in the environmental crusade by appealing to its economic self-interest. And this appeal takes its shape in the form of enlightened governmental policies and pressures exerted by the consuming public.

President Nixon spoke to this point in his message to the Congress on the environment this year when he said: "Our goal must be to harness the powerful mechanisms of the marketplace, with its automatic incentives and restraints, to encourage improvement in the quality of life."

In general, the federal government must use its taxing authority to make it more expensive to pollute than not to pollute. This can be achieved through such devices as directly taxing the lead in gasoline and the sulfur in fuel, both of which have been proposed by the President, or through offering tax credits to those corporations which install pollution control equipment. But no matter what the technique utilized, the end result should be to put the polluter at a competitive disadvantage.

Where injury to our environment cannot be readily prevented through judicious application of the laws of the marketplace, government must use its regulatory powers—either separately or in addition to a related tax payment—to discourage pollution. If the fines imposed were stiff enough, then results would be immediately evident.

Government's course appears reasonably clear, and there is no question but that we have made some progress. The Clean Air Act Amendments passed by the last Congress, for example, order the automobile industry to build by 1975 cars that are 90 percent cleaner than those which exist today—and auto exhaust fumes are responsible for between 60 and 80 percent of our air pollution. Similarly, the Federal Water Pollution Control Act Amendments, which passed the Senate unanimously on November 2, would authorize $16.8 billion over four years in an effort to make the nation's waterways virtually pollution-free by 1985.

Yet it is naive to argue, as some careless observers of politics and government have done, that if Congress were to act responsibly for a few months, we would be well down the road toward solving our environmental prob-

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Remarks by United States Senator Charles H. Percy.

lems. The environment is a "motherhood" issue, so this simplistic line of reasoning goes, and any delay in implementing new anti-pollution laws must be ascribed to the venality or stupidity—or both—of the politicians.

Quite simply, this is bunk. It is true that there is no overt propollution lobby, but it is also true that any changes which involve serious economic dislocations will have some enemies, and the environment has its share. More to the point, however, "Where there are priorities there is politics," as Mayor John Lindsay of New York City has so accurately observed. And when competing interests struggle for limited federal funds, someone invariably loses.

The question is not whether or not we want clean air. Everyone, in and out of government, certainly does. The question is whether we want clean air more than we want, say, a sophisticated new weapons system. We will know that our commitment to the environment is genuine when we agree to pay the price—and only then. And the price tag will be very high. President Nixon's Council on Environmental Quality estimates that the environmental cleanup cost through fiscal 1975 will be about $105 billion, from both federal and nonfederal sources.

How can we convince our fellow Americans and the national government that the environment deserves precedence in our list of priorities? That, I think, is principally the role of education, though government and even business and technology to a lesser degree have an educative function.

No one expects institutions of higher learning to begin proselytizing for the conservation movement. But ignorance distorts our values, and our educational system has within it the power to alert large segments of our society to the full implications of our environmental crisis. If the American public understands the magnitude of this crisis, I am confident that the environment will move to the top of the list of priorities through its own force.

One change in the educational system that offers hope for a deeper and broader knowledge of the environment is the interdisciplinary approach that has been introduced in many colleges and universities. In the past, the traditional compartmentalization of areas such as physics, biology, chemistry, botany, and geology has limited the effectiveness of studies of environmental questions. Today, we see many examples of the new academic eclecticism that should remove superfluous barriers to knowledge. And perhaps the best example I know of can be found at the University of Illinois College of Agriculture. I wish to commend you for undertaking an interdisciplinary, task-force approach to environmental research, which promises to be very productive.

In the last analysis, it is an educated public that will prod business, move government, and shape priorities. We Republicans ordinarily do not cite Thomas Jefferson, but I believe his words are appropriate here: "I know of no safe depository of the ultimate powers of society but the people themselves, and if we think them not enlightened enough to exercise their control with a wholesome discretion, the remedy is not to take it away from them, but to inform their discretion."

I cannot believe, for example, that the average American consumer will *knowingly* choose a product that contaminates his air or water if an alternative that does not is available. And, looking ahead, I cannot believe that we will *consciously* ignore the specter that overpopulation casts over us all.

Incurable optimism is not required to make these statements, just some confidence in the ultimate wisdom of the majority in a democracy. But sound choices come only from knowledge—and education's role is to disseminate it.

The place of technology in a program of environmental management is at once vital and fraught with danger.

The history of American technology is so studded with successes, that I am completely persuaded that we eventually will have at our disposal the means to manipulate our future—to cleanse our air and water at comparatively low cost, to recycle our wastes, to make our teeming cities habitable. If we were to turn the creative genius that carried us to the moon on the problems of the environment, the reverberations would be likely to be felt around the world.

At the same time, however, science has often been too quick to apply knowledge without a full understanding of its ecological ramifications.

Our garbage incinerators destroy waste, but they intensify air pollution.

Our smog-control devices reduce emission of waste fuel, but worsen the pollution caused by nitrogen oxides.

Our nitrogen fertilizers increase the food supply by adding nutrients to the soil, but the drainage waters can add nitrate pollutants to our streams and lakes.

And consider this grisly example, which actually happened recently in Malaysia:

In an effort to kill off disease-bearing mosquitoes in Malaysia, American technologists sprayed woods and swamplands with DDT. As a result, cockroaches which ate poisoned mosquitoes were so slowed in their reactions that they could be eaten by a variety of tree-climbing lizard which, sickened in turn, could be eaten by cats, which promptly died of insecticide poisoning. With the death of the cats, rat population increased; as rats multiplied, so did fleas. Hence, the rapid spread of bubonic plague in Malaysia.

But this is not all. The tree-climbing lizards, having died, could no longer eat an insect which fed upon the straw thatching of the natives' huts. So, as Malaysians died of plague, their roofs literally caved in above their heads.

It appears self-evident that the power of our technological forces may be fatal to our environmental system if we do not abandon the reckless procedure of polluting first and investigating and correcting mistakes later.

Science has an obligation to educate the public on the predictable effects of new technologies *before* they intrude upon the environment; it is not enough to offer the wisdom of hindsight. An educated citizenry should make the final public-policy decision on whether the benefits of a particular technological advance outweigh its hazards. But science must provide the information that will permit these value judgments to be made with what Jefferson called "wholesome discretion."

The single most important thought I would like to leave with you today is simply this: As human beings, as consumers, we all live in environmental glass houses, and we will achieve nothing if we continue to throw stones at each other. If we are sincerely interested in preserving and protecting our Earth, it is futile to attempt to assess blame for the conditions we face today.

Let me quote President Nixon on this subject: "The fight against pollution ... is not a search for villains. For the most part, the damage done to our environment has not been the work of evil men .... It results not so much from choices made, as from choices neglected; not from malign intention, but from failure to take into account the full consequences of our action."

It seems to me apparent that a positive program, with a broad base of support and with the emphasis on cooperation and coordination, is required to reclaim the environment, and that name-calling can only be an impediment to progress.

If we agree to work together, to abjure emotionalism and embrace the facts, I believe that in time we can repay our debt to nature and rescue our planet.

And we must, for the quality of our lives cannot be separated from the quality of our Earth. No amount of food, no dwelling, no material comfort will compensate for the loss of beauty and the loss of humanity that the degradation of our environment involves. Thoreau stated this truth succinctly: "What is the use of a house if you haven't got a tolerable planet to put it on?"

Regulatory Agencies

If we are to satisfy the needs and concerns of society in environmental matters, we must consider the elements that are involved. We begin with *physical resources* involving the entire state of Illinois. We deal mainly with the biosphere. Resources that we are concerned with are air, water, and soil. It is the responsibility of persons attending this conference and of administrative agencies to protect the state's twenty million acres of harvested crop land which is some of the most productive land on earth. Only recently have we gained an awareness that we must consider the soil resource not for our lifetime but for a hundred, a thousand, or a hundred thousand years. So the first point I make is that we must be concerned with the physical resources.

Next we have roughly ten million humans in Illinois and we'll have more tomorrow. There are farmers, factory workers, scientists, professionals, politicians, and citizens with other diverse occupations. The *human resource* is the second element we need to be concerned with as we consider societal needs. Humans, individually and collectively, through their activities impinge on the environment. In return, the environment and pollution of the environment impinge on people, on their economy, their welfare, their enjoyment, and their health.

The third element involved in arriving at societal decisions on environmental issues is the whole complex of *administrative agencies* of the Act under which we operate. The Illinois Environmental Protection Act of 1970 is the most comprehensive act in the United States. It provides a mechanism for determining the concerns and desires of society and for implementing them. The Environmental Protection Act embodies an enormous delegation of power by the state legislature to an administrative agency. The Act established three related groups. The Pollution Control *Board* is one of these groups. It makes regulations and sets standards. It also serves as a panel of judges. The Environmental Protection *Agency* is the enforcement arm. It monitors, conducts surveillance, and prosecutes cases before the Pollution Control Board for alleged violations of the standards. Finally, the *Institute* for Environmental Quality is primarily responsible for research.

With that brief explanation of the functions of the Board, Agency, and Institute, let's consider how they attempt to meet the "needs" of society. By the way, what are "societal needs?" I know what my needs are. You know what your needs are. But what are "societal needs?" I wonder who articulates them? Who decides what they are? In short, I ask who speaks for society? The question has no simple answer. Without being unduly critical, I feel that it is fair to say that most of the concern to this point has been generated by well-intentioned "environmental activists." They have made a substantial contribution to determining societal desires. Someone must generate concern and focus attention on issues. This leads to commitment of time and resources to do something about problems. Environmental activists have performed this important, constructive role. It has been accomplished to a large extent, I think, in consort with the news media. The news media enjoy dealing with environmental issues and they have effectively generated concern on the part of the general public. There are also a large number of special interest groups. Their limitation is that they have "tunnel vision." They think in terms of their own aims, goals, and objectives. Other than these groups, most people are unaware, to a great extent, of what is happening. They know pollution problems exist, but are not very much involved in determining the responses of society.

With this general background, I will explain how one administrative agency, the Illinois Pollution Control Board, functions. I shall address myself only to the area of rules,

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Report by S. R. Aldrich, member of the Illinois Pollution Control Board, on leave from his position as professor of soil fertility extension in the University of Illinois Department of Agronomy.

regulations, and standards, rather than to our responsibility in connection with permits, enforcement cases, and variances. We have three important problems. First, how to select the areas that we should consider regulating. Second, what to use as the basis for our decisions? Third, what is the process for review of rules, regulations, and standards once these are promulgated. Are they "set in concrete," so to speak?

In selecting subjects for consideration, we rely first upon evaluations by Board members. The Board at the present time is made up of three lawyers, an engineer, and myself. My background is in agriculture, specifically in soil fertility. Obviously the Board has within itself rather limited technical resources. Some choices are easily made; for example, mercury. We decided it deserved high priority and quickly set standards for mercury. In agriculture, the first area to receive attention by the Board was plant nutrients. Livestock wastes and sediment will be considered at a future time.

Second, proposals may be initiated and sent to the Board by our sister agencies, the Environmental Protection Agency and the Institute for Environmental Quality.

A third source of initiative is the Federal Environmental Protection Agency. The Federal EPA tells the state of Illinois, and every other state, that there are certain things we must do. We must set water quality standards for interstate waters by a specified date. They told us that we must set thermal standards for Lake Michigan and the Ohio, Wabash, and Mississippi rivers. We were required to set dates for secondary treatments for cities that discharge sewage effluence into large interstate rivers—the Ohio, Wabash, and Mississippi. We had to set air quality standards, and by a certain date to develop *episode* plans for Chicago and St. Louis in case of air inversions. What power of persuasion do Federal agencies have? It is substantial. The federal grant program in environmental matters involves great sums of money. We have been told, on more than one occasion, to meet deadlines or else Illinois grants would be in jeopardy. We have occasionally asked for additional time when our hearings were not completed, hence, we hadn't made the decision. They have not as yet withheld grant money, but the threat remains as a stimulus to meet the deadlines.

Fourth and finally, in Illinois under the Act, citizens may require us to hold hearings on rules, regulations, and standards. Two hundred signatures are needed on the petition. Hence, every individual can't force the Board to hold hearings. Three issues that have come before us as a result of citizen initiative are: (1) noise around O'Hare Airport; (2) a five-cent deposit on bottles, and (3) a proposed ban on phosphates in detergents. In summary, the four sources of initiative for regulations and standards are the Board, our sister agencies, the federal EPA, and citizens.

The second step by the Board is to obtain a basis for decisions on rules, regulations, and standards. The Illinois Environmental Protection Act requires the Board to consider (a) technical feasibility (is the technology available to accomplish the goal), and (b) economic reasonableness. The matter of economic reasonableness requires the Board to decide how far to go in imposing all pollution abatement that is technically feasible because of the serious consequences on the economy as a whole, on certain segments, or on individuals. I remarked earlier that within the Board we have limited technical expertise. Our critics often challenge us on this point. In our plant nutrient hearings, several farmers told us, in all seriousness, that agriculture is so important that the Board should include at least two full-time farmers. Having served on the Board, I can state that I do not agree with their view. I do, however, recognize the limit of expertise within the five members.

How does the Board obtain the information it needs for sound decisions? First, we make extensive use of *technical advisors*. The University of Illinois and the State Water Survey, Geological Survey, and Natural History Survey are believed by many to be the largest concentration in the U.S. of scientific expertise to deal with environmental matters. This resource of scientists has been extremely helpful during the first year of our operation. On ten different occasions we asked someone or a group from the University or one of the Surveys to present to us in an informal way background information on the state of the art so that we could decide whether an issue was important and whether the Board ought to propose regulations or standards. The assistance that we requested was never denied. Several of the groups that conferred with the Board have now been formalized into working committees. Several are now continuing groups functioning at the request of the Institute for Environmental Quality. The Pollution Control Board makes a great deal of use of technical advisory persons. For example, there is an expert in Georgia whom we consider to be the best available on radiation problems. We bring him either to testify at hearings or just to confer informally with us.

The second source of information for the Board is the *scientific literature*. In the first few months we made extensive use of this source. Each of us has a full-time assistant. My assistant is a Ph.D. in biology from the University of Illinois, Dr. John Allin. He has been very helpful in reviewing the literature and updating me in a concise way on the state of the art on particular environmental issues.

The main source of information that provides a basis for decision is *the public hearing process*. Public hearings are required in the Act. Though I had some misgivings about whether the hearings would become circuses, I am extremely happy over the way they have worked. I expect public hearings to become increasingly important in other states and at the national level. In the hearing process, we have expert witnesses appearing on behalf of many groups: the Board itself or one of our sister agencies (the Agency or Institute); industry; concerned groups, such as the Issac Walton League, Audubon Society, and the League of Women Voters; and finally individual citizens, some technically trained, others only desiring to present a layman's view. No citizen is refused an opportunity to put information into the hearing process. These are the sources of information in the hearing process itself.

To this point I have described how we select a topic to deal with, present a proposal, and hold public hearings. Next the Board makes a tentative proposal and distributes it for public review for two to four weeks. If substantial new information is generated and it appears that our record is incomplete, we then schedule additional hearings. Otherwise, after a period of opportunity for public review and comment, we make the decision and publish it. Decisions of the Board in Illinois have the status of law. They are not dependent upon the legislature for enactment.

In the process that I have described, the decisions are made by concerned individuals chosen for their judgment and integrity. They are not infallible. Furthermore, situations change, new pollution abatement technology develops, and the cost of control changes. My final comment is, therefore, to the effect that after rules, regulations, and standards have been promulgated, it is relatively easy to review them. The decisions of an administrative agency are more easily reconsidered than laws of the legislature. The Board on its own initiative may reconsider at any time. The Act provides that citizens may request a review six months after adoption.

The Environmental Protection Act appears to be serving the intended purpose quite well.

Agricultural Chemicals

I want to break my subject into two parts, fertilizers and pest control products. There are a good many other agricultural chemicals, as most of you know.

Fertilizers

Fertilizers have made tremendous contributions to the health and welfare of our people and to the preeminent position that the American farmer holds on the world scene. Norman Borlaug has said that the Green Revolution could not proceed without fertilizer; it indeed would not now exist without it. The miracle semi-dwarf wheats widely planted in the developing countries alone accounted for 8 percent of the total wheat output of the world in 1970 *(1)*.* The report of the United Nations task force on the protein crisis *(2)* reminds us that the Green Revolution brought self-sufficiency in wheat to West Pakistan in 1968 for the first time. In India, wheat production has nearly doubled in the last seven years—12 million tons production in 1964-65 (pre-Green Revolution) as compared with an expected 21 million tons in 1971. Also, protein on a world basis is in extremely short supply, and the crop content of this vital foodstuff is markedly affected by the amount and kind of fertilizers applied. It is certain that fertilizer use must continue and expand greatly throughout the world if the disastrous effects of food shortages and malnutrition are to be minimized or averted.

It has been pointed out *(3)* that restrictions on fertilizer use in this country could drastically reduce crop output. For example, grapefruit production would fall by 94 percent, celery production by 69 percent, and vegetable production by 25 to 55 percent if fertilizer use was prohibited *(4)*. Even moderate reductions in fertilizer use rates would produce not inconsiderable effects on food prices. Furthermore, millions of acres of marginal land would be brought into production in attempts to make up the food deficit, posing an environmental threat that is possibly beyond our imagination *(3)*.

Nitrogen

In respect to the environment, the fertilizer elements of concern are primarily nitrogen, and secondly, phosphorus. It would seem appropriate to reevaluate the U.S.P.H.S. drinking water standard governing the permissible limit of nitrates in public water supplies. Professor McGauhey of the University of California reported to the 12th Sanitary Engineering Conference at the University of Illinois last year *(5)* that "a considerable search of the literature fails to document the proposition that we are indeed confronted with any serious problems involving nitrates per se in water." He also remarked that the traditional concepts and process-design objectives of sewage treatment have been the production of nitrates. Paul Ward of the California State Department of Health reported at the same conference that in 1962, 85 community water systems in California were serving water at some time of the year with nitrates greater than 45 mg./1. (the federal standard) in the whole or only part of the distribution system (many greatly exceeding this level) and yet "there has never been a reported case of infant cyanosis (methemoglobinemia) in California that was related to ingestion of high-nitrate water." Indeed the National Institute of Environmental Health Science has found no instance in the United States where infant methemoglobinemia was caused by nitrates in public water supplies nor, for that matter, in baby foods *(6)*. Thus, it is not surprising that levels of 90 p.p.m. nitrate (or twice the federal standard) are permitted in the state of California. I don't want to belabor this point but I believe it is worth some further consideration.

Objections to nitrates in water have been raised on the basis of recreational or esthetic considerations. Apart from the fact that over 40 species of algae can fix nitrogen from the air, and thus require only an atmospheric source of this element, studies have shown *(7)* that as little as 0.3 p.p.m. nitrogen (or 1.4 p.p.m. nitrate) in water is sufficient to produce obnoxious algal blooms, given the right conditions. Needless to say, a certain minimum level of nitrate is required to support those aquatic species of plants that serve as food for fish.

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*All such references are to the literature cited at end of paper.

Report by John Stewart, a representative of International Minerals and Chemical Corp.

Phosphorus

The phosphorus needs of algae are extremely low, 15 parts per billion in water being capable of supporting "nuisance" blooms *(8)*. C. A. Black *(9)* reported that the phosphorus concentration in the soil solution in most soils is well above that required for algal growth, because of the readiness with which phosphorus reacts with other soil constituents, although little of it enters streams via the ground water. Most of the contribution of soils and fertilizers to the phosphorus content of streams is derived from surface runoff.

Black presents evidence to show that leachates, even from phosphate-deficient soils, will contain sufficient phosphorus to support abundant algal growth, since the concentration of this element which will sustain these unicellular plants is far below that required by the higher plants.

Most of the phosphorus which enters streams from soils is associated with the sediments that have been transported by runoff water *(9)*. These sediments may serve as a reservoir of phosphorus for aquatic plants. We do not fully understand the role of these phosphate-containing sediments in water pollution, and a great deal more research in this area is indicated.

Reducing Fertilizer Pollution

Surely agricultural land contributes to the enrichment of surface waters with the two elements under discussion. I want to discuss briefly a few measures which offer some promise in reducing the contribution from this source.

"Slow-release" fertilizers. They include compounds such as metal ammonium phosphates, urea formaldehyde, IBDE (isobutylidine diurea), CDU (crotonylidene diurea), and fertilizers coated with sulfur, waxes, resin (Osmocote), or asphalt. They are now costly and may be relatively low in "analysis" and economics would seem to restrict their use to high-value crops. They do offer some hope of reducing leaching and denitrification losses, and may require less frequent application to soils.

Nitrification inhibitors. These retard the enzymatic oxidation of ammonium to nitrite and nitrate and include such compounds as 2-chloro-6 (trichloromethyl) - pyridene (N Serve), 2-amino-4 chloro-6 methyl pyrimidine (AM), and potassium azide. These may reduce nitrogen losses from soil under some conditions by suppressing the activity of the bacteria which oxidize soil nitrogen or fertilizer nitrogen to nitrate. N Serve will apparently delay or suppress nitrification for about a month after application. It is expected to cost the farmer about $1.50 to $2.50 per acre treated when and if it is cleared for farm use.

Barriers. A thin barrier layer of asphalt, clay, composted garbage, or peat placed 18 to 24 inches deep in sandy soils will conserve water and reduce the possibility of leaching of nutrients. This would lead to more efficient use of fertilizer nutrients. Such an asphalt barrier may cost $200 to $300 per acre, and at this time could only be justified for relatively high-value crops. Other problems, such as flooding and accumulation of salts, must be solved before the technique could be adopted on a wide range of soils.

Denitrification. As much as 30 percent of the applied nitrogen under Illinois conditions may be lost to the atmosphere by this bacteria-mediated phenomenon *(10)*. This does not contribute nitrogen to natural waters, but if the process were understood and could be controlled it might be possible to dispel nitrates from the soil profile during periods when no crop cover is present and nitrates are available for leaching.

It is evident that we cannot contemplate the prospect of a reduction in fertilizer rates, or much of our efforts in attempting to raise crop yields through hybridization, technological innovation, improvements in pest control, etc., will come to naught.

Research is needed to determine the dimensions of the problem of nutrients in water and that involves a quantification of the contributions from all of the various sources. We need more precise measurements of the needs of crops for nitrogen especially, so that wasteful use can be avoided. It is imperative in our research work in soil fertility that we assess agronomic, economic, as well as environmental factors. In all this we must weigh the advantages of a course of action against the disadvantages, always bearing in mind the common good.

Pesticides

Technological innovations—commercial fertilizers, crop chemicals, even row-crop systems themselves—carry with them the possibility of both benefits and detriments. In striving to improve our technology we must give due regard to public safety—air, water, and soil must be kept, insofar as possible, free from harmful or even unpleasant contaminants. Some chemicals, particularly the persistent pesticides, in doing their wondrous work contribute unwanted substances to the environment. Natural controls for pests (parasites, insect and bird predators, insect diseases, cultural or mechanical methods) suggest themselves.

From early times these measures have been tested, sometimes successfully, in meeting pest problems. Because of environmental concerns we today are placing much more emphasis on such measures. I want to mention some matters which deserve consideration in relation to the substitution of biological control measures in place of synthetic organic chemical pesticides.

First of all, if we are to have a progressive, healthy agriculture, one capable of providing adequate amounts of food and fibre for our needs, we must accept the need for compromises between environmental quality and the need of the environment to produce the necessities of life. We must apply the time-honored and proven device of the cost:benefit ratio, since every benefit or improvement is not without cost. Dr. Metcalf dealt very capably with these matters in our earlier discussions.

Sophisticated, efficient chemical insecticides were developed during World War II and have been widely and effectively used since then. However, real and imagined drawbacks such as insect resistance, toxicity, environmental pollution, destruction of beneficial insects and wildlife, residues on foodstuffs, and legal restrictions have made necessary the development of more selective methods of insect control to supplement the synthetic organic chemical armory. These selective methods can be separated into two categories: chemical and biological. The chemical selectives include hormones such as the "juvenile" hormone, and the sex-attractant pheromones. These are undergoing much study now, but they have not yet been made available to farmers in place of the synthetic chemicals for protection of his crops.

Biological control methods, including breeding for plant resistance, the release of sterile males, use of predators and parasites, and microbials such as bacteria and viruses, offer much promise and are being studied and promoted as an alternative to synthetic organic pesticides.

Bacterials such as *B. thuringiensis* have for some years been used successfully for control of tent caterpillars, cankerworms, cabbage loopers, gypsy moth larvae, and others. My company, after many years' work in the development of a viral insecticide effective against members of the genus Heliothis (cotton bollworm, corn earworm, tobacco budworm, and tomato fruitworm) obtained clearance in late 1970 from the FDA and the USDA to treat large acreages of cotton to establish the efficacy and safety of the product. This viral insecticide is "narrow spectrum"—it is selective for members of the genus Heliothis only, and is innocuous to natural predators and other insect pests as well.

Some years ago von Rumker et al. *(11)* estimated that the cost of the research and development effort to bring a new pesticide to the market is in excess of 4 million dollars. Further, this cost will be much the same whether the product is "broad spectrum"—effective on say 100 or more insects—or a selective agent which controls only one or two insects. Obviously the very selectivity which makes such a product highly attractive from an ecological point of view, makes it much less attractive as a viable commercial venture. The sales volume of such a specific agent would need to approximate 2.5 million dollars with a maximum of 10 million dollars annually to justify the expenditures necessary to its development *(11)*.

The selective chemical pesticides represented by the hormones and pheromones and their analogs continue to be the subject of research and development in industrial laboratories. This class of compounds offers the possibility of patentable products and this would give some protection to the venture money required in their successful commercial development. Yet the feasibility of such an effective narrow-spectrum chemical pesticide still awaits practical demonstration.

Unlike chemicals, however, microbials, being preparations of naturally occurring organisms, are not patentable in the United States and in most industrialized countries. Therefore, an effective microbial insecticide cannot enjoy the advantages of the protected market which accrue to manufacturers of patentable products.

A major factor in the development of a microbial pesticide is the cost of the safety evaluation required for government clearance. If this could be borne by the public body, say through the USDA-ARS program on pesticide research, the eventual replacement of hazardous or objectionable chemicals with biological control measures could be hastened, to the benefit of the environment. It is possible that special tax credits or other incentives might also provide the encouragement necessary to accelerate the development of selective, safe, and non-polluting pesticides. To further the progress in biological control in general, and microbial control particularly, additional protection and incentives to industrial participation must be given.

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Environmental Protection From Food Processing Wastes

Campbell Soup Company plants are located in a wide variety of places, from older plants located in the Chicago and the Camden, New Jersey, areas, to newer ones in more out-of-the-way or rural places. During the past ten to twenty years, the company has had a policy of trying to get away from urbanization by locating plants in relatively rural areas. In doing so, we have had the opportunity of investigating a variety of waste-treatment processes, ranging from the more conventional trickling filter, activated sludge-type systems, and lagoon systems to spray irrigation systems. I would like to center my talk this morning on a somewhat unique adaptation of a spray-irrigation system at our Paris, Texas, canned food plant, to show how we have met the environmental-quality challenge in this location.

The normal concept of spray irrigation is that of applying a waste water to relatively sandy soils, have it percolate or infiltrate into the ground, and eventually get into the ground water. Our work at Paris and one or two other locations has shown that even with a relatively tight, clay soil, where the infiltration is zero or very small, we can still achieve a very high waste-disposal efficiency. We call this an overland-flow, spray irrigation system.

The waste water is applied at the top of a specially prepared slope, ranging in length, top to bottom, from 200 to 300 feet. The slope is such that we get a very gentle uniform flow. The waste water is applied at the top of each slope, runs down along the slope, and collects in a specially prepared waterway. This waterway joins waterways from other slopes to become a small stream running through and eventually leaving the property.

The plant has some twenty acres under roof and a total area of 500 acres. The plant processes result in a raw waste water flow upwards of 3.6 million gallons a day. The area in which this treatment system is located was formerly a cotton farm. The farming practices were very poor and when we took over the property, roughly the early 1960's, the whole 500 acres was in extremely bad condition. Some erosion gullies were so large that you could hide a D-7 bulldozer in them. Before the plant was built we developed and instituted an overall plan of slopes, terraces, waterways, etc. Before the plant actually went into operation, we set up a watering system with fresh water so that we could get the grass to develop and mature before we actually started putting waste water on it.

We use water for vegetable washing, food processing, equipment cleanup, etc. The food processing waste water first goes through a grease separation unit and then through a series of rotary drum waste screens where most of the solid matter will be taken out. It is then put into a reservoir of some 100,000-gallon capacity and pumped with a series of turbine pumps through an underground force-main system out to each slope. At the slopes the force-main then comes above ground and conventional aluminum irrigation pipe is used to distribute the water along the top of the slopes.

When we initially put this system in, we had a lot to learn and we have learned it through operating this system. We can get much better land utilization than we have so far. Through a one-year program, which we completed in 1969, we studied a wide variety of things ranging from climatological effects on the irrigation system to chemical reductions in the waste water and found that we can reduce the length of the slopes. By decreasing a slope to only 200 feet from 250 or 300, we can obtain the same quality of effluent with much better land utilization.

At the Paris plant, the grass is harvested one to three times a year. The grass has to be, of course, fairly water-tolerant because we are applying half an inch of waste water a day. We have found that reed canary grass has been an excellent grass to adapt to these slopes. When grass harvesting is not done, say through the winter months, one irrigation line will operate for roughly six hours and be rested for a period of up to eighteen hours. During harvesting, and this is done of course in the warmer weather, we have to take areas out of service so that they can be dried long enough for a mower to come in and cut them. We have found that we can operate on a schedule whereby a particular area may receive waste water for six hours but then have a rest period of only ten or twelve hours.

The quality and quantity of waste water coming off a slope are measured. We use a standard H-flume arrangement with a water level recorder placed on it. A pipe leads into a drum in which samples are collected for chemical analyses.

We found that the reed canary grass has provided us with an exceptionally high quality hay. It has ranged all the way up to as much as 23 percent crude protein and has had twice the mineral value of local hays being used in the Paris area. Knowing this, we conducted a brief experiment to find out the palatability of the hay. We used a number of beef cattle grown in the Paris area, offering them the reed canary grass grown from our particular plots and other hay which they had been accustomed to eating. The cattle showed a marked preference for the reed canary grass over what they had been eating. Harvesting and selling the hay has given us a return of at least 10 percent of our costs to operate this system.

The raw waste water shows a biological oxygen demand (degree of contamination) which ranges from 550 to 1,000 parts per million. In the final field effluent, the water which is actually running off our property, the BOD is down to as low as 3.3 parts per million which is really equivalent to a lot of streams in that area.

We found that all spray irrigation systems that we have

Remarks by D. D. Deemer, Environmental Engineer with Campbell Soup Company.

operated have a tremendous capacity for absorbing shocks such as large changes in pH or other waste water characteristics. For example, in a processing plant like the one at Paris, Texas, we generally have two shifts of food processing and a night shift of clean up. The characteristics of the waste water change markedly from the daytime operation to the nighttime clean up. However, whether daytime, nighttime, or weekends, the system has consistently produced an effluent which is very close to constant in pH, BOD, or whatever parameter examined. The system also has a large capacity for absorbing shock hydraulic loads. Although it is designed on the basis of a flow rate of three to three and a half million gallons a day, this system can handle loads of one and a half to two times in excess of its designed capacity without any noticeable decrease in its efficiency.

Concerned Citizens

After Dr. Miller asked me to appear on this panel as a concerned citizen, I began to wonder if that wasn't just a polite term for what Dr. Norman Borlaug recently called "a fear-provoking irresponsible environmentalist." Dr. Borlaug went on to say, "The moving forces behind the environmental movement today include the Sierra Club, the National Audubon Society, the Isaac Walton League and the Boone and Crockett Club, and the Environmental Defense Fund." Since I am a card-carrying member of all the organizations except the Boone and Crockett Club, I think I probably fit the description very well.

The reasons for my concern are not purely sentimental and not purely scientific either; I suppose they are a mixture. Also since my training is in agriculture and my work is in agriculture but the other half of my time is spent on my real love which is environmental matters, I have a chance to look at things from both sides. I think one of the main reasons for my concern as a birdwatcher, naturally, is the massive reproductive failures of so many of our avian species like the Paraguayan falcon, the bald eagle, the brown pelicans. The geological record certainly did not prepare us for such massive failures in the reproductive ability of such well-established species. I am also concerned because the coral beach in Florida where my husband and I have been going for twenty years is now covered with oil. We can no longer walk along the beach without getting oil all over our sneakers. I am also concerned because when I go back to New York to visit my mother every year and I look down from the plane and try to see the skyline, most of the time it is shrouded in smog.

I recall a class twenty years ago in which the professor advised us that we could make lakes more productive by adding fertilizers to the water. I don't know whether they are still giving that advice anymore. I don't think any of us would argue with the fact that there has been a tremendous change in our technology in the postwar years and that nowhere has this change been greater than in agriculture.

Since I read all the releases from the Extension Service, I know that one of the things that people in agriculture are proudest of is the fact that our food costs us very little compared with what many people in other countries are paying. In other words, the housewife has to pay a smaller percent of her complete budget for food than many other housewives. Well, I suppose it is odd for a housewife to complain that food prices are too low but, in essence, that is exactly what I am doing. Barry Commoner in his new book, *The Closing Circle*, has popularized the phrase, "There's no such thing as a free lunch." I don't think I have been getting a free lunch, but I would say the waiter has made a mistake in the bill, and I think the cashier is going to catch the error before we get out of the restaurant.

I hope that whatever is accomplished at this meeting people will look at the full problem. Part of the problem has been that everybody wants a cleaner environment, but nobody is willing to pay the price. Some of us are now realizing that we must pay back our debt to the environment and add these costs to the consumer's food bill. In order to figure out these full costs, we have to look at all aspects of food-production cycle—not only the manures and residues that have been discussed at this meeting but also the price which farmers are paying for the things they buy. For example, if the electric companies would add up their full costs and pay for controlling their stack emissions, the price of electric power would go up. If the strip-mine operators who sell them their coal would do a better job reclaiming the land, the price of fossil fuels would go up. If the petrochemical companies cleaned up their field production methods and didn't spill so much oil on the way to the refineries, the price of fertilizers and gasoline would go up. If the people who are mining rock phosphates in Florida would do a better job of reclaiming that land after open pit mining, the price of phosphate fertilizers would go up. Finally, when we finish adding up all these costs, I hope we also add up, on the complete balance sheet, the cost in terms of the energy cycle. Until we have this all figured out and compared, the energy inputs and the energy outputs, I don't think that we can boast American farming is the most successful in the world.

Remarks by Judith Joy, farm editor of the Centralia, Illinois, Sentinel.

Emerson was not really thinking of agriculture when he wrote his essay on compensation but I think the phrase "for every benefit gained there is a tax levied" could apply very well to agriculture. All attendant reforms will have certain pitfalls. For example, if we have more farmers using zero-tillage, we are probably going to end up using herbicides and we may be encouraging more farmers to put steeper land into row crops. If we switch the alfalfa farmers from using alfatox in the spring and have them spray parathion in the fall, we may be saving the little wasps that parasitize the weevils, but there is a greater human risk and the parathion may end up damaging some other beneficial species. If we limit our use of fertilizers, we may have to plow up more pastures and woodlots and raise our food costs. Thus, I think each course has to be plotted very carefully.

I rather think that the present generation of Americans has had more in the way of material possessions than any other generation can possibly expect.

The Concerns and Worries of Farmers

I want to talk a little about the worries and the concerns of the farmer as they relate to the environmental situation that we are in today. Just what are they thinking about? To be fair about it, we don't want to inject our own feelings too much, so we make a telephone call to some friends and ask, "Just what is the worry? What is the concern? Are we meeting the needs in the environmental situation? What does it look like to you in agriculture?"

I had some interesting responses.

For the first gentleman I called who has a good livestock operation and is a pretty good corn producer, the talk went like this:

"What are you worried about?"

He said, "Tax situation might be bad, had a pretty good corn crop, made a few bucks on the cattle."

"Is that all you are worried about?"

"Well," he said, "the 41¢ calves I bought may be touch and go."

"What about this environmental situation?"

He said, "I haven't heard too much about it. I really don't think it bothers me too much. I run a pretty good ship all the time. We handle quite a few acres. I think our operation is proper. We haven't gone into some of the newfangled ideas of liquid manure spreaders. Maybe we are still a little old-fashioned, although we have a good power takeoff rake and a good loader on the tractor. We keep running 300 or 400 head of cattle. I don't think this situation is going to bother me at all. Maybe I'm lucky I'm not close to any surface water supply or the stream. Our drainage district does a pretty good job in draining the whole township for us. I think that environmental quality must be somebody else's problem and not really mine."

"Is this all the situation is about? No other concern or no other worry?"

"No," he said. "You know I think we were a little bit lucky this year. We fussed and fumed a bit early. We paid high-priced dollars for seed corn, had to pay a little more this year. Then the seed corn man said, 'I don't know about it, Bill, this corn might not be too good. You know we had some blight. We got you a blend here. Don't depend on it too much.' Then we had an awfully good crop. So I guess the situation isn't too bad."

With another call, we get an opposite answer to the same questions.

"Well," he said, "the crop was just fair. I don't know about these regulations that I keep reading about in the paper. We had a pretty good meeting at the Soil Conservation office. An extension man gave us a little talk. They projected various types of regulations that we should be looking out for, limitations on plant fertilizer, insecticides, pesticides."

"Well, do you use these things?"

"Certainly, I use these things."

"What about the insecticide and pesticide situation?"

He said, "You know I have never seen a third of all these bugs that these insecticides are supposed to be killing, but my farm papers tell me they are pretty good. My crop has been better. I am going to have to think two or three times about whether I am going to change it or not. Our situation in the agriculture community is fine. The air looks good. I went into the big city for a meeting and, boy, it was sure good to get back home and get a good drink of water and breathe some of this fresh air. Our situation really isn't too bad out here. So why are we going to be confronted with these regulations? That's too much."

"What about regulations?"

"I'm concerned about the people who developed these regulations. Have they considered everything? Do they know our situation as it really is? The projection of the plant nutrient regulation seems plenty safe. The rate is up pretty high. It is more than we are using. Maybe I haven't been using enough stuff. I have been going to try to use more. But on the other hand, if after a while they find we aren't using nearly this much but our nitrate situation doesn't correct anything, they may bind this thing down a

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Remarks by Joseph Berta, Superintendent, Division of Soil and Water Conservation Service, Illinois Department of Agriculture.

little bit on me and really put me into a squeeze. Is this really my problem? I think we have pretty good tillage methods. I think we could still take a drink out of our tile line as long as it is not the one that comes out of septic tank. We should remember where we hook into these lines. We were always told that the good old soil we deal with filters things out pretty well. Maybe the regulations can go too far."

A farmer says, "Did you hear about what happened over in the neighboring county? They are emptying the lagoon from Chicago and bringing sludge out into the country. They are squirting it up in the air so that you can see it for miles. It looks pretty black and messy on the ground. Is this O.K. but my operation bad? Who in the world is making the decisions on this? The man comes into the county with an EPA permit and the public health permit, but we think we operate in agriculture without these permits. Why do I have to sit in back and let somebody else make these decisions?

"They tell me that in the city now it is against the law to burn the garbage. We are going to bury it out on the farm. And yet, is my situation wrong?

"I know I'm not putting on too much fertilizer because the economics of this situation comes in. They said, 'You know you can go only so far, Sam, and then you better take another look at it because it is not going to balance out dollar-wise.'

"I am not ready to leave the farm yet. I don't intend to be squeezed out of it and not say anything. I would hope that the competition in the whole state of Illinois, as well as with the neighboring state, would be equal. I would hope that Illinois didn't jump too fast and set up something that would overregulate it to that point.

"When I stop to think about it, and I am speaking as an agricultural man and a farmer, that's the city fellow's problem and not really mine. It is difficult for me to understand how the urban man is going to get away with putting his restrictions on me. He seems to squeeze me a little bit when it comes time for a strike, and I can't do anything about it."

The agricultural man is going to depend on what information he gets from his university and from industry. We are not going to break up a good relationship between the industry and the agricultural man unless we can show them why the situation is going to be interrupted. The farmer has been able to lean on the industry, even to financing some of his fertilizer, to get a particular job done. I think that the farmer is ready to listen to reason. He is a little suspicious because he is a pretty independent fellow. He made his decisions, and he either floated or he drowned with those same decisions. He makes those decisions every year.

What are we going to do? It is difficult to get the farmer to even understand that he should change, although he has accepted much change through the years. The whole farm picture has changed. Some of us argue with him a little bit and say, "You have made some foolish mistakes with your changes. You gave up diversification in agriculture. Why?" "It didn't look like it was the profitable thing to do," is his answer.

To the west and to the southwest of the Mississippi River they don't have the high-quality land that we have in Illinois. It doesn't pay us to put a lot of livestock on our good soil, so we will let them do it and we will provide corn. They are recognizing that maybe they shouldn't have planted all that corn and irrigated out there in the south and the southwest. We have created tremendous ability to produce feed grains. We just don't have the animals to put it through, here in Illinois. Farmers are a little suspicious of the change they have to face, of the regulations we are talking about. Many of them would like to get back into the livestock business, one way or another. It is a difficult decision to make—the size of the operation they could get into, etc.—if all of the details we are talking about in proposed regulations will have to be met. So I think that if we are going to solve some of the misunderstanding in the agricultural community, we are going to have to get to this man in an understandable way. Our present-day farmer's situation is different from that of an individual operator. We have big landowners but we have more big operators than we have big landowners, and they deal with three, four, and five different landowners. These landowners are fighting a cost squeeze. It is easy to show a pretty picture of a good-looking steak in the counter and say, "If we are going to raise this livestock in a manner that is not going to pollute the society, we are going to take all the precautions. You are going to invest in this. You are going to have to get more money for your project." Fine. All the farmer wants to know is, "When am I going to start getting more money for this product? I am ready to go. When are we going to start changing this whole system for me, so that I can get my hands on a couple of those bucks. I'm ready to go. We start tomorrow. Bring the man in with the machine."

Really, I think, you gentlemen are obligated to go into detail and show where this balance starts and where this balance stops, where it hits a good center that says, "We don't have to have a large number of acres, into the thousands, in order to survive in this situation. Diversification is still a pretty good way to go. It is still a good life in agriculture. We can help you and guide you."

The agricultural man understands as much about the wildlife and the ecology of this situation as anyone. I drove a tractor many an hour myself, and I really didn't care about the bald eagle because I never saw one. My favorite was the red-winged blackbird. He took on most of these bigger birds that come around. He was really particular where he sat. The meadowlark knew just how long she could sit on the nest and how much fuss she could make until we would actually hear her, on that big diesel tractor, and would stop and try not to touch anything in the nest while we attempted to move it to save it for her. We looked out for these situations. The average Illinois farmer, the average farmer in the Midwest, looks at these situations today. Since he is not in the business of attempting to destroy the environment, he is a little hesitant in accepting the change or accepting the proposed regulation that is going to regulate his life.

Agricultural people may take your advice, and they may have to weigh it a time or two. Many of you gentlemen know Jim Holderman, from Grundy County, who probably was the first man who really went in for big acres in narrow-row corn. He was a neighbor of mine, a fine gentleman. I would venture to say we didn't jump in very fast after Jim started in on narrow-row corn. It fell down flat many a year. He had to make his own machine to pick it. But narrow rows gradually started rubbing off a little bit and we began to say, "Well, this is a good idea, I think we will change." The total community isn't going to change with every newfangled idea. In many cases we would rather have someone else do it while we will watch it pretty close. "We will listen," they tell me, "to our farm organization. We belong to a pretty good farm organization. It will warn us in advance about the regulation, whether we should go far with it, whether we should adjust to it. If we have to adjust, I suppose we will. We want to be sure the people developing these regulations and rules, or proposing them, are considering just what the situation is, whether we really need them.

One fellow smiled at me and he said, "Joe, I don't think I have a problem. Nobody has ever come around and tested the water on my place or checked any run-off, so I must be all right. The family is healthy. The livestock are doing well. Look at that beautiful crop of corn and soybeans. Where can you see a better picture than that? This must be somebody else's problem. How in our society can they accuse me of doing something wrong when they have never even come in my back yard and checked it?"

This is what the agricultural people in Illinois are thinking about right now.

The Natural Environment--A Public Concern

When I was invited to speak to you about the natural environment, several questions were suggested as a guide: How do we assemble information put forth by professional people into a form that is useful? How do we understand what people at the grassroots are thinking about? How do we get these two things together? How do the professionals achieve the best utilization of the time of the concerned amateur? I think these are real questions.

You gentlemen have expressed some very interesting thoughts. I hope that I can carry the information I get from you, in whose purpose and integrity I have confidence, to some of the young folks with whom I deal very much. I try to relate things they can think about constructively and usefully and to increase their confidence in various branches of government and in the integrity of purpose of a great institution like this.

Since I left public office a year ago April I have participated in about 270 discussions—student groups, TV programs, and the like, dealing with real problems that must be clearly understood. These are things an ordinary person can understand. I hope such discussions help counteract confusions and angers and that as a consequence your university will be able to operate more freely so that real professionals, like Sam Aldrich here, can have the benefit of the freedom of professional decision with less political interference and shortsightedness than I dealt with, principally in Springfield. This was the reason I left—I would not be a party to things I can speak of with such fervent contempt. In my judgment, we haven't much time to correct some of these things we are concerned about. I don't think we can fool ourselves with the idea that, if we flub this one, our children and our grandchildren will have an equal opportunity to bring about the corrections that are obviously necessary.

I am speaking as an amateur to you professionals. I have a very strong feeling as an amateur that we are just playing, even in the very vital things you are doing, unless we face up to some greater issues such as overpopulation. We have to find answers. At the rate we are going, we will run out of the soil fertility and productivity before we run out of newborn babies. I think the young people with whom I deal feel this keenly. I think there is a feeling, however you choose to express it, about the worth of the falcons and eagles that I too am concerned about or the blackbirds that you enjoy. I think there is a very real sense in America of a change of attitude.

We lawyers speak of the truth, the whole truth, and nothing but the truth. I come to you to get truth, to get facts. The *whole* truth is equally important. What are we going to do with it? I think there is a concern in America, a fear, and an anxiety. The housewife who asks a simple question, "What kind of soap or detergent can I use? I am tired of judging by the size of the box and the color and all this propaganda that comes out," is expressing this concern. People can't find something they can trust and believe in. These are vital things challenging you.

I hope you continue this conference as a regular event. I hope I can be privileged to enjoy your hospitality again because it means a great deal to me to get a feeling that here are people who care and know, and do not operate on guesswork. You do not operate at the political level where most decisions are made that are so frightening. Such conferences can be a source of real information.

I am pleased that leadership to meet the need for knowledge has arisen in the College of Agriculture, one of many groups in Illinois and our nation that could have taken the lead. I hope the psychologists, members of the law school, the political scientists, and others will also become involved. Wouldn't it be nice if lawyers were informed? That would be a great start right there. An old judge said to me, "Give me facts first, then we will talk about law." I think if you could put facts and information into the law school and get lawyers at discussions like these before they deal in fuzzy cloudlike things, it would

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Remarks by William Rutherford, attorney at law, Peoria, Illinois.

be a great public contribution. I think it is important to get the involvement of your marketing people in the psychology of the marketplace and ways to get these ideas across—ideas that have been perverted in the views of many of us by the Madison Avenue approach. How do we get this mission of yours accomplished, this highest of missions of teaching and research, which I look upon as simply an element by which you gain truth and fact, to inspire the young people and multiply their usefulness? You don't get this just in the ordinary and well-done efforts of your extension education because it is such a crisis situation. The time is so short, the need is so vital, and the time is so right in the minds of those who are hungry for something they can believe in and trust and partake of. How can you fortify extension education with psychology, marketing, law, all these other things you can put into this, so that you can sell these ideas to many more, more realistically and more constructively than ever has been done before?

The Senator spoke about the 1899 law that was first put in use in 1969. The youngsters feel strongly about this and say, "They pass laws but they don't mean a damn thing! It is just to put us to sleep, to spend more money, build more bureaucracy." What is the guts of the purpose if a federal refuse act lies on the books, unused? The Senator spoke about a utility that had only been asked about this year after all these decades. That is because informed people are now concerned enough to ask questions. This is the power of a free people to express themselves and bring about needed changes. My generation can't kid these young people. We talk about all the fine things of government and business and ideals and the Judeo-Christian philosophy and all the rest. We say, "Just do it our way; just be patient, it's doing fine," when all the tangible evidence they can see, feel, taste, and smell is befouled. It's been done, in great part, by my generation.

Talk about the gross national product and cost-benefit ratios makes me retch because it doesn't say the real thing. It's like having all your scientific measurements done in linear measurements without taking into account volume or temperature. We haven't been told the things we have to know to equate and use if we have any feeling of stewardship for our grandchildren. What kind of life are we presenting to them? I have talked to clubs of older men my age. They all say, "Gee, is it really that bad?" They go back and get into their Olds 98's and Cadillacs and don't do a thing about the situation except maybe sell a little faster before a regulation makes it awkward for them. But the kids see it. We have a golden age and a golden place because we have these inquiring minds. I have spoken to some of the angry groups, too, and found them intensely well informed, eager to help and participate if they believe you are not kidding them, that you haven't got some catch that shows up later on, and that you are not only telling them the truth but also the whole truth and nothing but the truth. People are sick and tired of shoeboxes, race track stock, public aid scandals, and all these other things that damn government in both parties. They see the venal misuse of patronage politics as a short-time thing only for reelection. They are sick of it; they are skeptical. When I talked at Knox College after Earth Week two years ago, a young barefoot guy that needed a shave and a haircut and all the rest of it came down the hall to me and said, "Mr. Rutherford, this is the first time in my life that anyone has shown me how we can correct these evils within this system." Be these issues emotional or not, they are still based upon lack of stewardship. The guy that sells electricity knows about the fly ash downwind. He knows the real cost is that which someone else is bearing and that it isn't carried forth in the ordinary presentation of dollars and cents. We aren't kidding these youngsters.

Even though there may not be a complete answer yet to the SO-2, I share the feeling that it is even a greater problem to find the problems of the SOB. These are the people who are misusing the principle of the ideals of free government. With all its faults, and they may be numerous, it is still the finest form of government. But who articulates that and believes it and is willing to make a few sacrifices and suffer a few inconveniences? This is where we are falling down and falling apart.

But to come back to you. Can you get other agencies to continue this work? This is a great mission. You who are teaching have to understand it's an evangelistic effort that has to be done to meet these things in the time I think our children have left. We have to understand the ordinary news media. We have to understand from the perspective of others. It's a little like I was told once when I was a youngster: If you want to find a mouse hole you better get your eyes down to the mouse's eye-level rather than yours. You are more likely to see where he is going. You who deal in the scientific world are now getting the interfacing between yourselves, which is absolutely great. You extend the power that lies in the genius and brilliance and concern of educated people, if you combine that with understanding and the kind thoughtfulness of the amateur. He means well but may be mistaken. But don't turn him off, don't make him angry because he has more votes than you and I have, if for no other reason. Give him things he can believe and trust and use. If he finds them fair, he will come back for more. Remember there are millions of places where any citizen who cares can be constructively engaged. God knows, we need places for constructive endeavor for the problems of this country.

Use your imagination to find places where these people can be useful. It's like my father used to tell me as a child about a jig-saw puzzle. The many pieces will never be put together as well with all the force and power and anger you can muster as by thoughtfulness. You put a piece here, and if it is wrong you move it a bit. It helps delineate the shape and outlines the gap for someone else to put a piece in the puzzle. We ought to use this approach, mundane and childlike as it may seem. We have to realize that government does not respond to needs, it responds to pressure. There is a vital difference. It took me a long time in the practice of law to accept that fundamental fact of life. The pressure should be constructively applied, based upon a full disclosure of fact with a little altruism that damn well wouldn't hurt America today. Put back in a little of the belief in the practicality and idealism, which is really the whole basis upon which we are free people, and get trust in return. Remember that good example is the best sermon, and find ways to put into words what the citizen can understand and believe. He knows what he tastes and drinks and is aware of the commotion and the noise. He reads *Life* magazine and sees the smog problem over New Jersey and the loss in the fishing industry throughout the whole world—technology misused and overrun. We can answer his concern. We can establish something, I think, that is as vital as all the things we can dream of, not just the meeting of the pollutional problem and the solution of some of the economic problems.

We have to clean up government. You know the fears that your neighbors express. What upsets us today? We have more money, we've got more of this, we've got more of that. But there is still fear and concern. I was in Brazil for a couple of days in February, and I like to use the cruzeiro as an example. When I was there twenty years ago, it was worth some five hundred dollars and last February it was worth two U.S. dollars. I simply say that this is the product of somebody's misuse of government. Somewhere along the line they permitted it to be misused and they admit misuse. They have gone from monetary crisis to monetary crisis.

The understanding of government and the citizens' concern about government is a new dimension for you who have been in the academic world and are free of some of the mundane dirty-type things of politics. I think we have a tool in the concern of youth. I think we have an opportunity to restore their confidence in the purpose of American government and the ideals we are supposed to have. I think we can see some different values through their eyes. I hope we will find measurements from you that we can equate into the tax law or into the industrial law or for the shareholder, if you will. The difference between the standard of living and the quality of life is one that is not academic.

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